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La Salle Park

Shoreline Erosion Abatement

City of Hamilton

City of Burlington

Halton Region
Conservation Authority

Hamilton Region
Conservation Authority

F.J.Reinders and
Associates Limited

September 1979

-416478

F.J.Reinders and Associates Limited

Planners, Engineers and Project Managers

November 19, 1979.

The Corporation of the
City of Burlington,
Box 5013,
Burlington, Ontario.
L7R 3Z6

Attention: Mr. Ross A. Stephen,
Landscape Architect,
Department of Recreation Services.

Dear Mr. Stephen:

We are pleased to submit our final report on the LaSalle Park Shoreline Erosion Abatement Study.

The report deals with the existing erosion problems and the basic design parameters. It furthermore discusses recreational and environmental aspects and outlines alternative and proposed solutions, as well as approval procedures and funding of the proposed project.

We are confident that the contents of this report will provide you with adequate guidance to assist in decisions regarding the implementation phase of the required work. We thank you for the confidence shown in our firm with this assignment and assure you of our dedicated assistance in the implementation.

Yours very truly,

F.J. REINDERS AND ASSOCIATES LIMITED

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Vice President

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LA SALLE PARK
SHORELINE EROSION ABATEMENT

PREPARED FOR

CITY OF HAMILTON

CITY OF BURLINGTON

HALTON REGION CONSERVATION AUTHORITY

HAMILTON REGION CONSERVATION AUTHORITY

BY

F.J. REINDERS AND ASSOCIATES LIMITED

NOVEMBER 1979

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1.0 SUMMARY

The erosion of the shoreline of LaSalle Park is mainly a result of blufftoe undercutting by wave action.

A soils investigation and slope stability analysis confirmed this situation and revealed that the sandy bluff slopes are safe from large deep-seated slides. Erosion due to run-off and groundwater flows were found to be of minor significance.

The existing wave climate has been determined. The LaSalle Park shoreline is subject to wave action with a maximum significant wave height of 1.2 metres (3.94 feet). This wave height occurs frequently enough to be used as a design condition. Since no advantage can be gained from offshore sediment movement, a shoreline protection strategy has to be based on dissipating the full impact of the design wave.

Upon comparison of alternative solutions such as beaches, seawalls and revetments, the most economic and advantageous shoreline protection method has been developed and is recommended herein.

Alternative methods to establish a stable slope have been developed and compared.

The recommended solution is a combination of a cutting and filling operation and a revegetation program for bare and disturbed bluff face areas.

The recommended erosion abatement program includes the following operations:

a. Construction of an armourstone revetment type shoreline protection structure at the toe of the west and east bluff sections.

b. Reshaping of the west bluff into a stable slope.

c. Revegetation of disturbed and bare slope faces.

d. Construction of granular berm and beach heads at the low central area.

The above outlined construction program has been devised in recognition of the following major design criteria:

a. Halt erosion.

b. Maintain natural setting of bluff faces and the central marshy area.

c. Limit filling operations in the harbour basin.

d. Allow existing and future boating activities.

Since construction operations require a work road along the entire waterline of the park it is recommended to construct the project in one phase.

Approvals from provincial and federal government agencies are not expected to present great difficulties in view of the necessity and modest nature of the project.

The project is eligible for financial assistance under the Provincial Conservation Authorities Act. Under this Act a maximum of 55% of the actual project price will be funded by the Provincial Government through its Ministry of Natural Resources. An additional 5% will be funded by the local Conservation Authority.

The total estimated construction cost for the project is $351,500.00 based on 1979 prices.

2.0 RECOMMENDATIONS

In view of the need for shoreline protection at LaSalle Park and the investigations and conclusions contained in this study report, we have summarized below our recommendations concerning remedial actions which both municipalities in question should adopt. It should be noted that the sequence of initiating the recommendations, when adopted, is extremely important with respect to acquisition of project funding, design and construction approval from all the pertinent agencies (See Section 13.0 and 14.0). This being the case, with the co-operation and counsel of the Technical Co-ordinating Committee established for this study, we have listed the recommendations in the strategic order that implementation should occur.

a. That the Cities of Hamilton and Burlington take immediate steps to combat the erosion problem along the shoreline of LaSalle Park and, that subsequent to the official adoption of this study report by the City of Burlington and the City of Hamilton, both municipalities enter into a cost sharing Agreement covering the 40% of the total estimated project cost not eligible for provincial or federal funding assistance.

b. That, on the basis of this study report, the Halton Region Conservation Authority be requested to officially adopt the LaSalle Park Erosion Abatement Project as a benefitting municipal capital project and take the necessary actions to acquire project funding approval from the Ministry of Natural Resources.

c. That engineering design and subsequent construction drawings and specifications for the LaSalle Park Erosion Abatement Project be prepared in 1980, preferably in the months of January and February.

d. That, based upon the preparation of construction drawings and specifications, the pertinent agencies be contacted for acquisition of project design approval.

e. That the construction of the proposed erosion abatement works be carried out in 1980, preferably in the months of July and August.

3.0 INTRODUCTION

LaSalle Park is located at the north shore of Hamilton Harbour (see Figure 1), and owned by the City of Hamilton. Development and maintenance costs are shared by the City of Burlington.

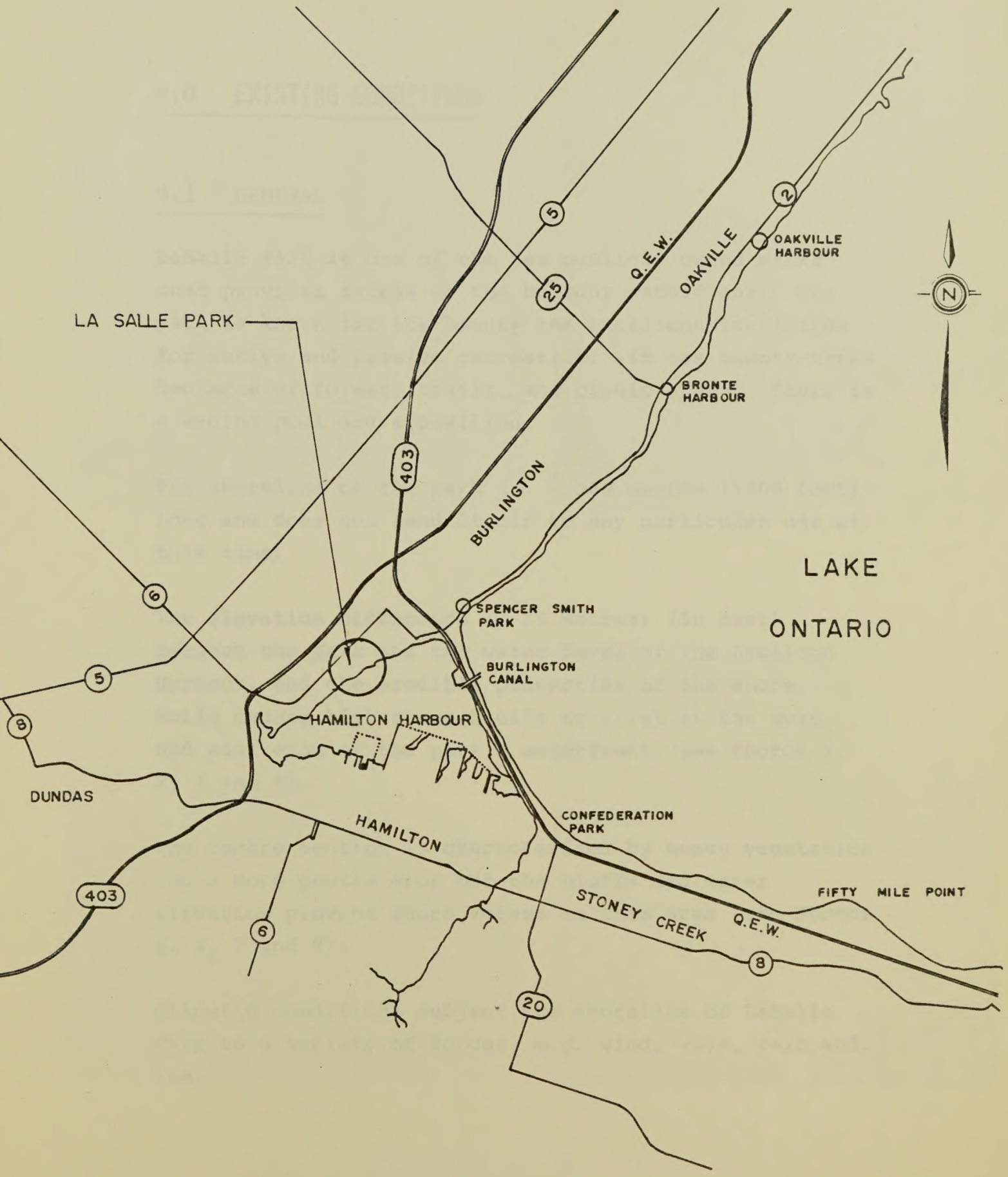
Ongoing erosion at the Hamilton Harbour waterfront of LaSalle Park led to the commissioning of this preliminary engineering study.

The erosion of the LaSalle Park shoreline is most prevalent along two stretches of the shoreline where high sand cliffs dominate.

Erosion of these cliffs results from the instability of the slope base and the surface erosion of the face material. Responsible agencies wish to carry out preventive measures and to establish a well-protected and safe waterfront.

Restoration of the shoreline of the park can be achieved through the provision of certain measures of control, designed and constructed to provide protection against wave action and safety against slope failure.

This report outlines the existing conditions, the erosion criteria, the design process and recommendations for erosion control measures.



SITE IDENTIFICATION

FIGURE 1

4.0 EXISTING CONDITIONS

4.1 GENERAL

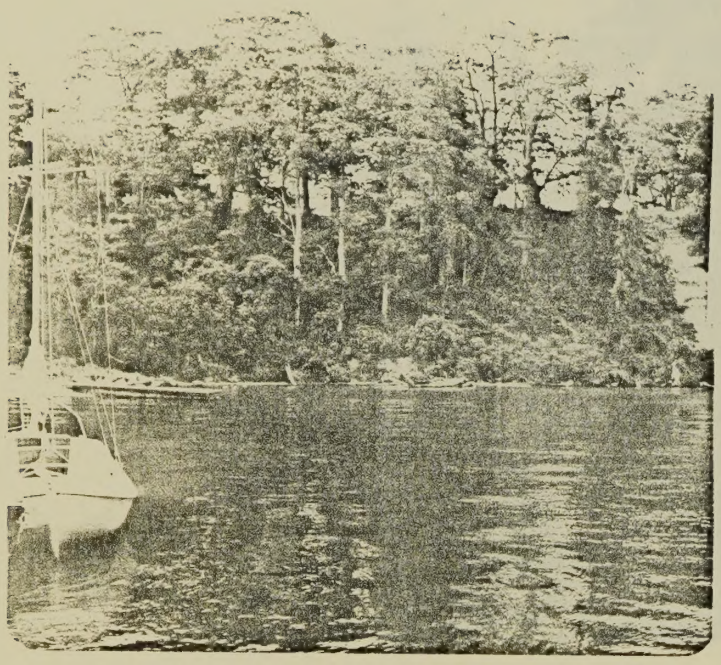
LaSalle Park is one of the few publicly owned parks that provides access to the harbour waterfront. The park is known for its beauty and excellent facilities for active and passive recreation. It has twenty-three hectares of forest, trails, and picnic areas. There is a wading pool and a pavilion.

The shoreline of the park is $\pm$ 580 metres (1900 feet) long and does not lend itself to any particular use at this time.

The elevation difference ($\pm$ 15 metres) (50 feet) between the park and the water level of the Hamilton Harbour, and the erodible properties of the shore soils causes high steep bluffs to exist at the west and east ends of the park's waterfront (see Photos 1, 2, 3 and 4).

The centre section is characterized by heavy vegetation and a more gentle drop but the bluffs and water elevation prevent shore access to this area (see Photos 5, 6, 7 and 8).

Climatic conditions subject the shoreline of LaSalle Park to a variety of forces, e.g. wind, wave, rain and ice.



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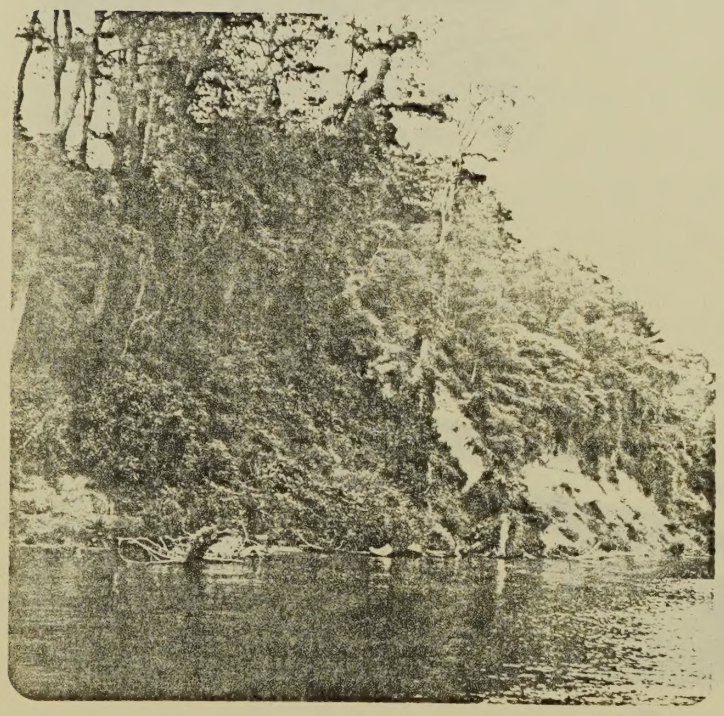

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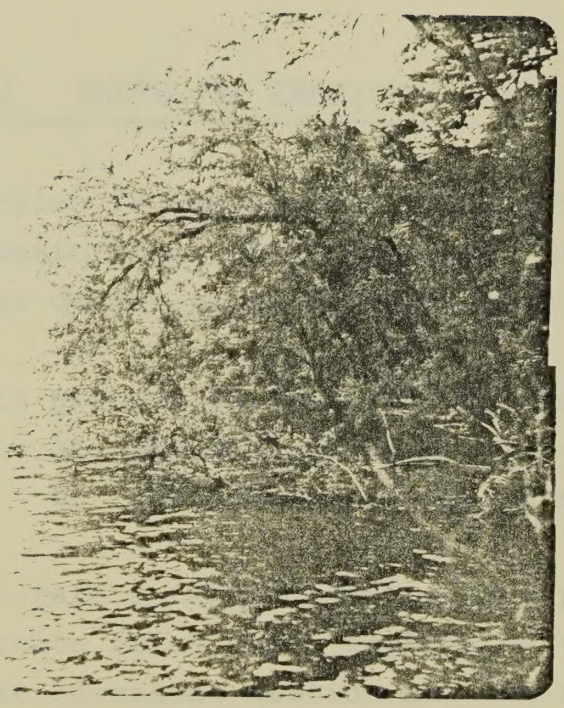
PHOTOS 1 - 4

(WEST AND EAST END OF EXISTING SHORELINE)



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PHOTOS 5 - 8

(EXISTING CENTRAL SHORELINE)

4.2 SHORELINE EROSION

Erosion is the process leading to the alteration and deterioration of shorelines. It is a natural process that occurs to some degree on all shorelines.

This process is dominated by two events:

a. the dislodging of material (weathering),
b. the removal of dislodged material.

The rate at which erosion of a particular shoreline section takes place depends on the physical nature of that shoreline section and the erosive forces applied.

The factors contributing to these dislodging and removal processes are many and complex and are the subject of much research by government and private enterprise.

The intent of this study is not to evaluate the ongoing erosion processes at LaSalle Park in the greatest detail, but to arrive at a suitable protection solution for the shoreline.

The erosion of the LaSalle Park shoreline is most prevalent at the foreshore areas of the two shoreline sections where high sand cliffs dominate. Recessions at the bluff rim do not appear to be as large as the foreshore recession.

Erosion of these cliffs results from the instability of the slope and the surface erosion of the face material.

Four mechanisms of erosion are evident:

a. undercutting of the bluff due to wave action, causing slope instability,
b. surface erosion due to slope instability,
c. frontal attacks on the slopes caused by various environmental forces (rain, wind, ice),
d. slope instability caused by access to the bluffs by birds and humans.

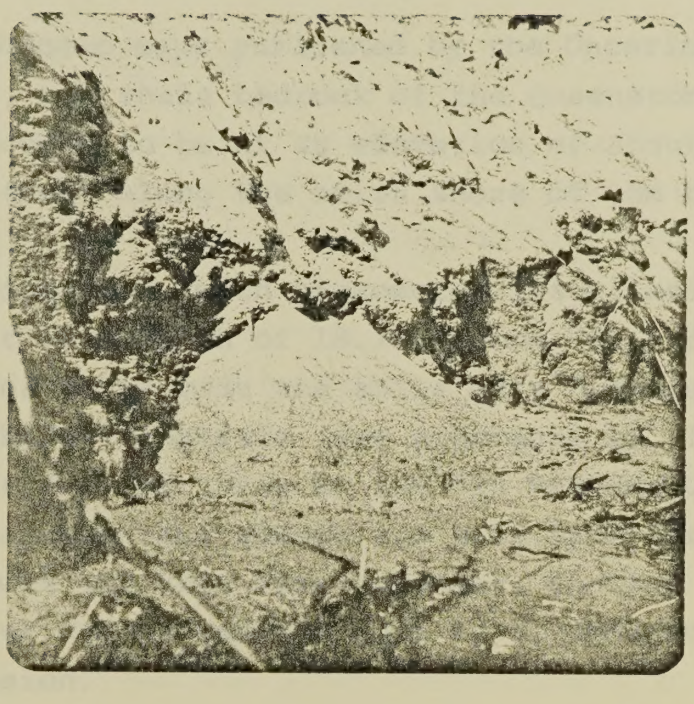
The first two erosion causes are the major contributors.

These facets have been analyzed in greater detail in order to determine the magnitude of the applied forces and to protect and eliminate the erosion problem.

4.3 SITE GEOLOGY

LaSalle Park consists of fields and bush on hills of sand. Along the shore, two steep $\pm$ 14 metres ($\pm$ 45 feet) bluffs dip sharply towards the bay. Some slope instability can be seen as sections of the bluffs have sloughed away recently (see Photos 9 and 10).

The area is part of a large beach deposit formed along the shores of Lake Iroquois which occupied the Lake Ontario basin during the Wisconsinan glacial period, more than 25,000 years ago. Drainage channels through these ancient beaches have left small valleys along the shore.



9.

10.

PHOTOS 9 - 10

(EXISTING BLUFF SLOUGHING)

According to geologic maps published by the Ontario Geologic Survey, red shale bedrock of the Queenston formation is thought to be at an elevation of about 53 metres (175 feet) along the north shore of the bay.

Borehole investigations, with piezometer installations, were carried out to a depth of 18.75 metres (61.5 feet) at the two slopes to provide the soils data required for a slope stability analysis (see Reference 1). This analysis was carried out using an IBM 370 Systems Computer and revealed that the sand slopes are safe from large deep-seated slides and that retrogressing, shallow slides will likely occur due to uniform soil type, undercutting and surface erosion.

Based on the piezometer installations and subsequent groundwater monitoring program, no evidence of a continuous static groundwater table has been found within the dense fine sand of the slopes.

No groundwater flow is occurring out of the slope face other than from localized coarse sand seams near the slope face and/or surficially softened soil layers caused by rainfall or freeze and thaw action. Localized coarse soil pockets will develop perched groundwater within themselves due to infiltrating runoff. This perched groundwater will seep slowly into the surrounding less pervious soil and is purely a temporary feature.

4.4 SURFACE DRAINAGE

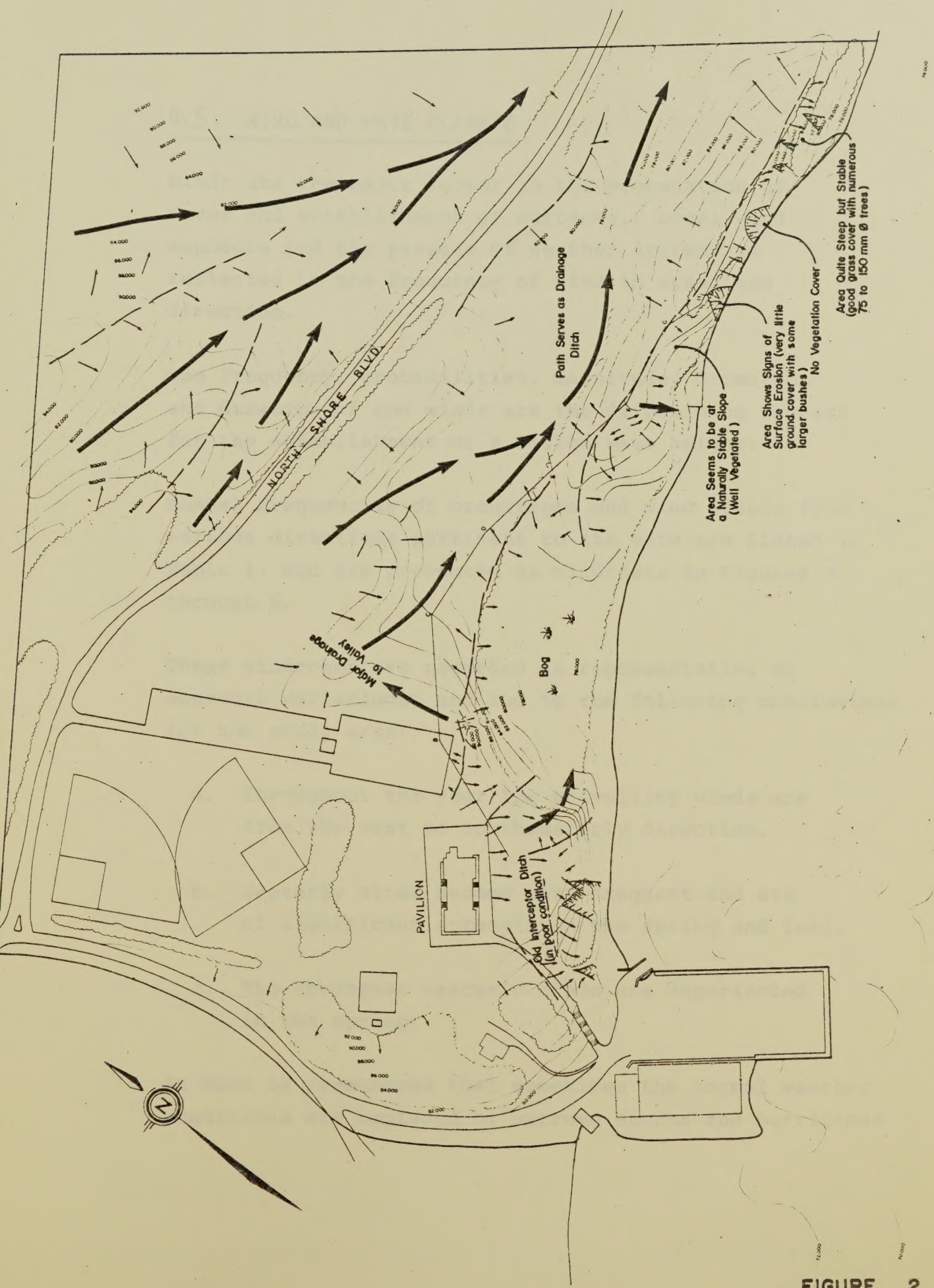
The hilly nature of the park results in a distinct surface drainage system. A ridge line follows the nature trail into the eastern portion of the park. Surface run-off water is therefore generally directed away from the shore into the central portion of the park and finds its way to the lake outside the easterly park boundary (see Figure 2).

The area surrounding the pavilion is gently graded in such a manner that water moves uniformly away from the structure in all directions. Minor ridge lines tend to concentrate some surface water especially into the bog area. Signs of erosion are minimal.

There appears to be an interceptor ditch immediately in front of a section of the western bluff but seems to have little affect as gullies continue to form down the slope. The land at the top of this bluff slopes away from its face which indicates that no surface water erosion is possible here.

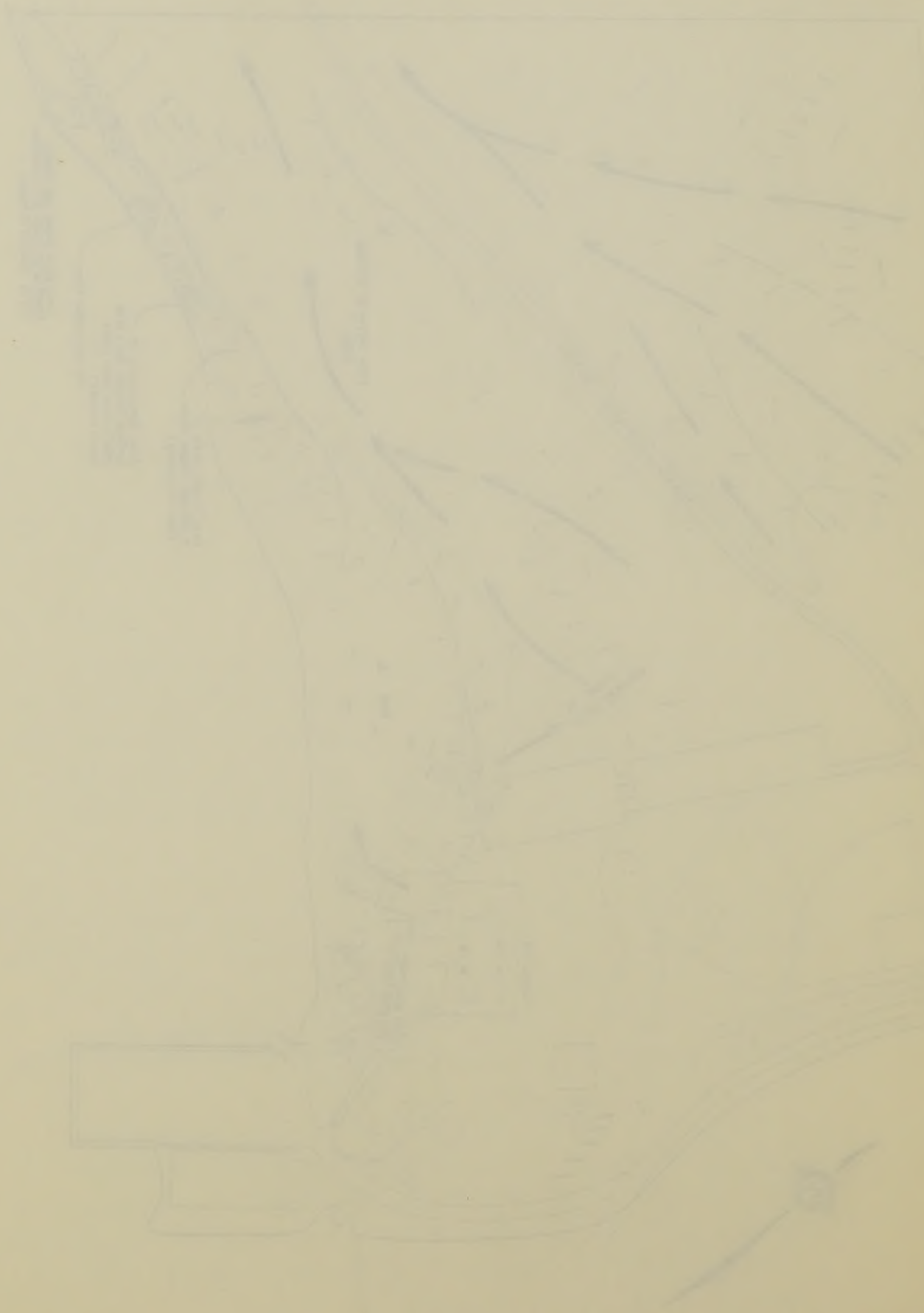
The trail at the eastern bluff acts as a drainage channel during storms. It shows signs of erosion as depressions and natural ditches make walking sometimes difficult. This water occasionally spills over the slope and develops small gullies, particularly at the eastern end.

In general, the land tends to slope away from the shoreline into a central valley resulting in little surface water flow over the bluff areas. Although some minor localized erosion is evident from this surface flow it does not substantially contribute to the erosion of the shoreline and back shore.



EXISTING SURFACE DRAINAGE PATTERNS

FIGURE 2



4.5 WIND AND WAVE CLIMATE

Winds are the major factor in the propagation of waves and establishment of currents. Local wind exposure and the passage of weather systems is reflected in the frequency of wind in speed and direction.

The frequency, probabilities, magnitude, direction and duration of the winds are the determining factors for the establishment of a design wave height.

Annual frequencies of occurrence and wind speeds from various directions pertinent to the site are listed in Table 1, and are presented as windroses in Figures 3 through 6.

These windroses are regarded as representative of seasonal variations, and led to the following conclusions for the study area:

a. Throughout the year the prevailing winds are from the west to southwesterly direction.

b. Easterly winds become more frequent and are of significant strength in the spring and fall.

c. The strongest easterly winds are experienced in the spring.

It must be remembered that sometimes the normal weather conditions are replaced by extreme storms and hurricanes.

TABLE I

Annual Frequencies of Occurrence and Wind Speeds (in kilometres per hour of winds from listed directions as recorded over the period 1955 - 1972).

Wind Direction	Hamilton Marine Police	Hamilton R.B.G.	Toronto International Airport	Toronto Islands
	Occurrence Frequency Percentage			
N	5	8	11	6
NE	17	14	8	10
E	11	8	4	16
SE	1	2	11	4
S	1	5	6	9
SW	4	35	21	19
W	2	19	11	15
NW	9	8	23	20
Calm	-	1	5	-
	Wind Speed in Kilometres per Hour			
N	14.2	9.5	14.5	13.7
NE	16.6	13.2	13.4	18.2
E	14.6	11.3	16.7	18.0
SE	8.9	8.9	13.7	13.5
S	9.0	12.7	12.5	15.9
SW	15.0	14.2	17.7	18.5
W	13.8	11.7	18.3	17.4
NW	17.7	13.4	17.7	17.4
ALL	14.8	12.7	15.5	17.2
Max.hourly wind	75.6	66.0	88.5	90.1
Max. gust for that wind	107.8	94.9	135.2	125.5

Taken from "Canadian Normals Volume 3. Environment Canada.

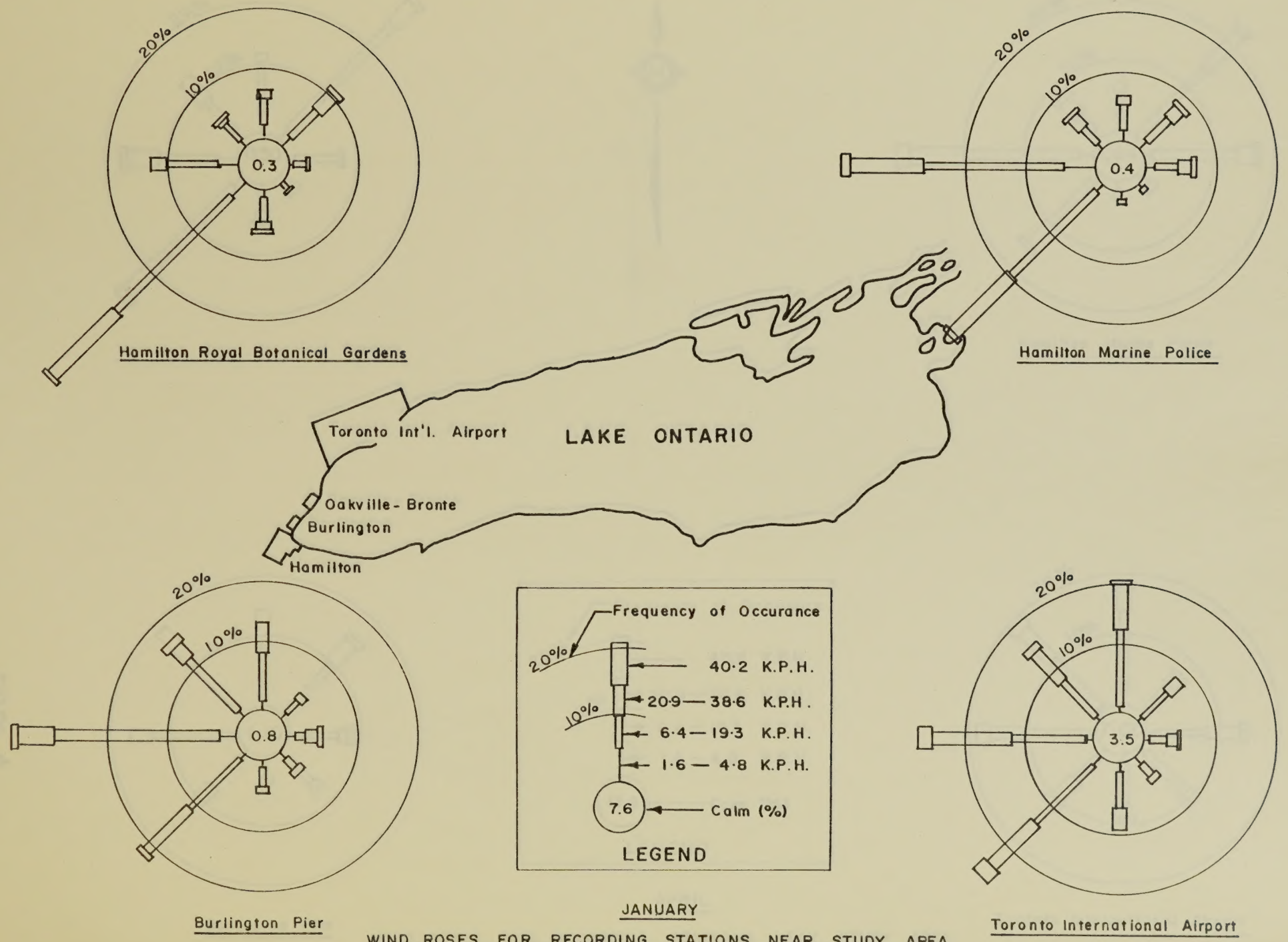
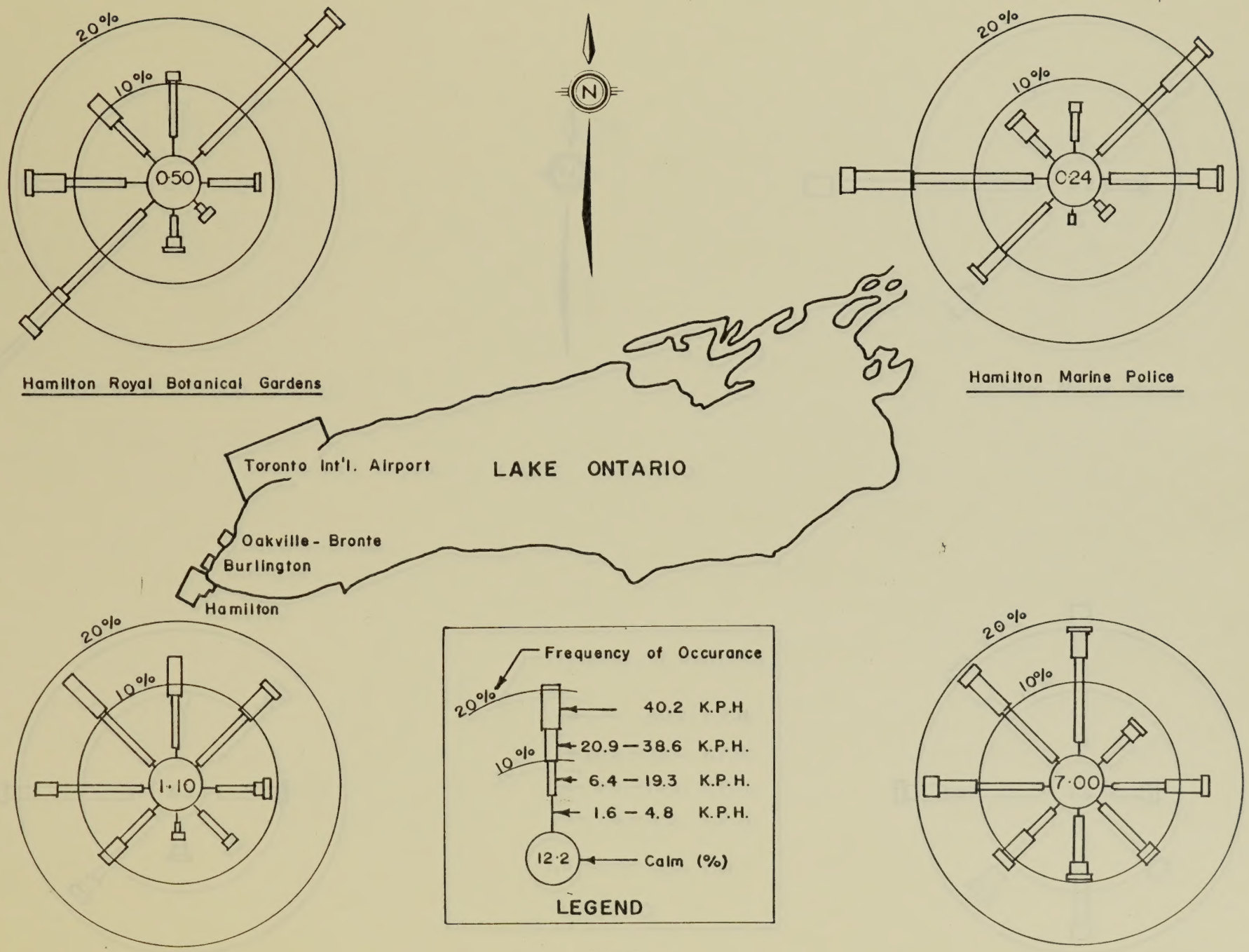


FIGURE 3

JANUARY

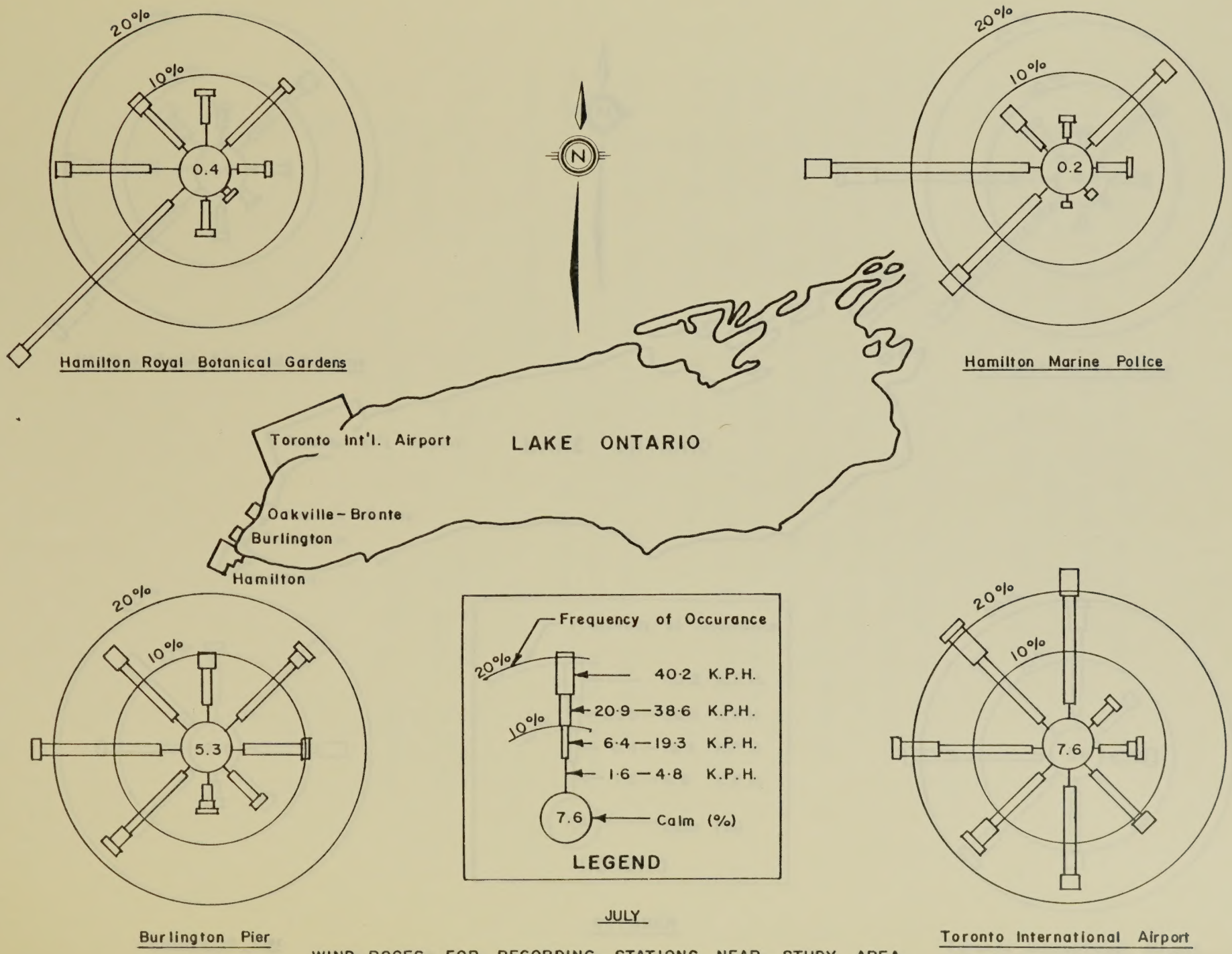
WIND ROSES FOR RECORDING STATIONS NEAR STUDY AREA



APRIL

WIND ROSES FOR RECORDING STATIONS NEAR STUDY AREA

FIGURE 4



JULY

FIGURE 5

WIND ROSES FOR RECORDING STATIONS NEAR STUDY AREA

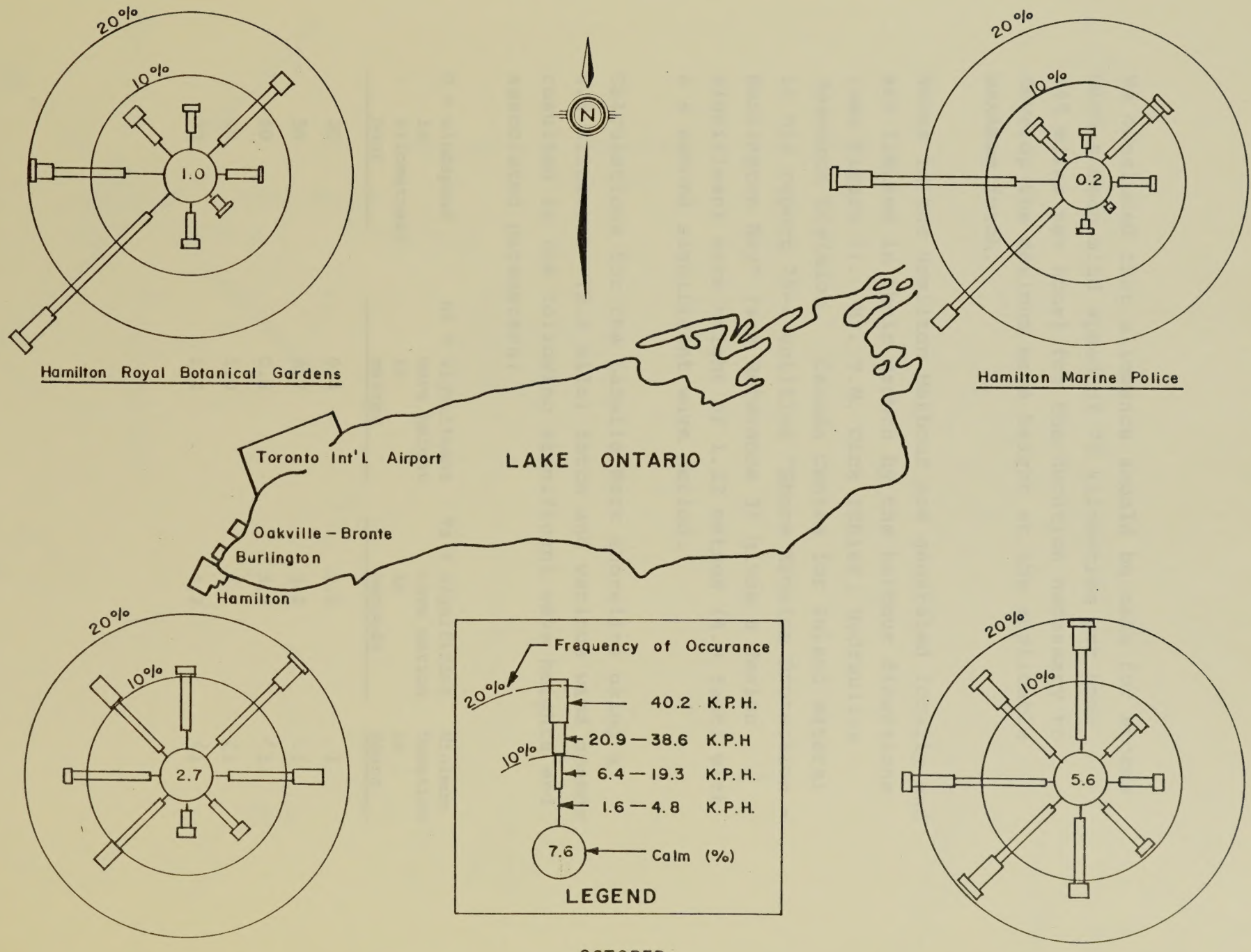


FIGURE 6

OCTOBER

WIND ROSES FOR RECORDING STATIONS NEAR STUDY AREA

We concluded that allowance should be made for storms with a mean wind speed of 72 kilometres per hour (45 miles per hour) for the duration necessary to develop the maximum wave height at the applicable maximum fetch.

Waves in the Hamilton Harbour are generated locally and are limited in their growth by the harbour dimensions (see Figure 7). Mr. T.M. Dick (Chief, Hydraulics Research Division, Canada Centre for Inland Waters) in his report 75-4 entitled "Shore Erosion Protection - Burlington Bay" (see Reference 3) gives a design significant wave height of 1.22 metres (4.0 feet) with a 4 second significant wave period.

Calculations for the LaSalle Park shoreline using a 4.8 kilometre (2.9 mile) fetch and various wind speeds resulted in the following significant wave heights and associated parameters:

U = windspeed in kilometres/ hour	Hs = significant wave height in metres	Ts = significant wave period in seconds	Minimum Duration in Hours
30	0.4	2.5	1
50	0.7	3.2	<1
60	0.8	3.7	<1
70	1.0	4	<1
80	1.2	4.2	<1

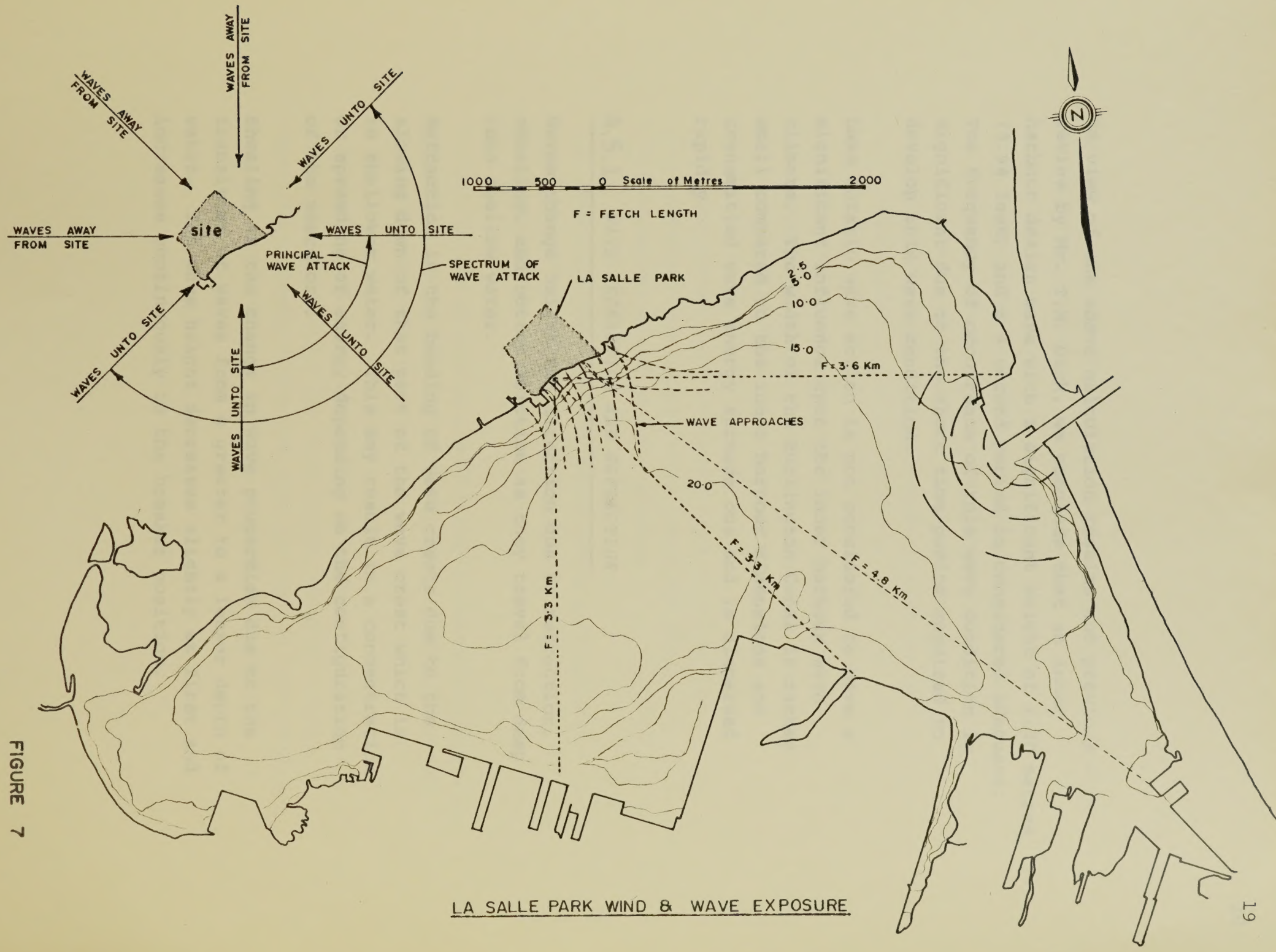


FIGURE 7

LA SALLE PARK WIND & WAVE EXPOSURE

In view of the above calculation results and previous review by Mr. T.M. Dick, we conclude that an inner harbour design wave with a significant height of 1.20 metres (3.94 feet) and a 4 second period is considered adequate. The frequency of occurrence of this wave condition is significant due to the short time period required to develop this wave condition.

Lake Ontario wave action is not considered to have a significant influence upon the inner harbour wave climate. The width of the Burlington Canal is rather small compared to the inner harbour dimensions and transmitted wave energy spreads out and is dispersed rapidly.

4.5.1 *WAVE REFRACTION AND REFLECTION*

Waves change height and direction due to refraction, shoaling, and bottom friction as they travel from deep into shallow water.

Refraction is the bending of wave crests due to the slowing down of that part of the wave crest which is in shallower water. This may result in a concentration or spreading of energy depending on the configuration of the nearshore.

Shoaling is the change in wave properties due to the transition of waves from a greater to a lesser depth of water. The wave height decreases slightly at first and increases continuously to the breaker position.

For the wave action in front of LaSalle Park the following wave behaviour patterns are recognized:

a. Although wave action in the Hamilton Harbour can be generated by winds from all directions, winds originating from the west through north to east do not generate waves dangerous to the study site.

b. Wavefronts arriving at the site from the opposite quadrants do affect the site directly, especially from the south to south-east.

c. Wave fronts from the south-east arive at the shoreline unrefracted and yield the most dangerous breaking wave heights.

d. Wave actions from the south and east-southeast are refracted and will yield lower onshore wave heights (see Figure 7).

In view of the governing south-easterly approach direction, a detailed refraction analysis for waves approaching the study site was not pursued.

Reflected waves from the LaSalle Park Dock do alter wave agitation in front of the study site. Easterly waves, especially, create reflected wave action off the LaSalle Park Dock resulting in a short crested wave pattern.

4.5.2 *BOAT GENERATED WAVES*

It is obvious that the earlier described design wave conditions are in excess of boat generated waves and no further attention has been given to those waves.

A check with the Hamilton Harbour Master's Office revealed that a commercial freighter can come within 300 metres (1000 feet) of the LaSalle Park Dock. However, this situation is not likely to occur since ships must anchor within a designated area further away from the dock and strict ship movement control is exercised by the Hamilton Harbour Master's Office.

Waves generated by a commercial freighter at the above stated distance will be insignificant in comparison to the possible wind generated waves.

4.6 WATER LEVELS

The water level of Hamilton Harbour follows closely the Lake Ontario water level fluctuations.

Changes in Lake Ontario water levels can be divided into three categories:

a. Short period (local disturbances, wave action, seiches, and set-up).
b. Long term (changes in supply).
c. Seasonal.

Regulation of Lake Ontario began in 1958 and attempts to provide the best possible compromise among the needs of power, shipping and property owners. The upper limit of 75.22 metres (246.8 feet) specified in the I.J.C. Orders of Approval cannot always be met and allowances for record levels such as those which occurred in 1973 (75.6 metres) must be made.

Since 1860, records have been kept of the levels of Lake Ontario and are shown in Figure 8 for the period of 1900 to 1978. It must be realized that the recorded levels are exceeded due to wind set-up and can reach heights up to 0.65 metres (2.1 feet) in excess of recorded mean levels. For the purpose of design, a maximum and minimum water level has been adopted as listed:

Maximum = Highest all-time monthly mean + wind set-up (June, 1952),
= 75.6 metres + 0.4 metres = 76.0 metres

Minimum = 73.6 metres being the minimum water level suggested by the I.J.C.

Elevations are in metres above mean water level at Father Point, Quebec (IGLD).

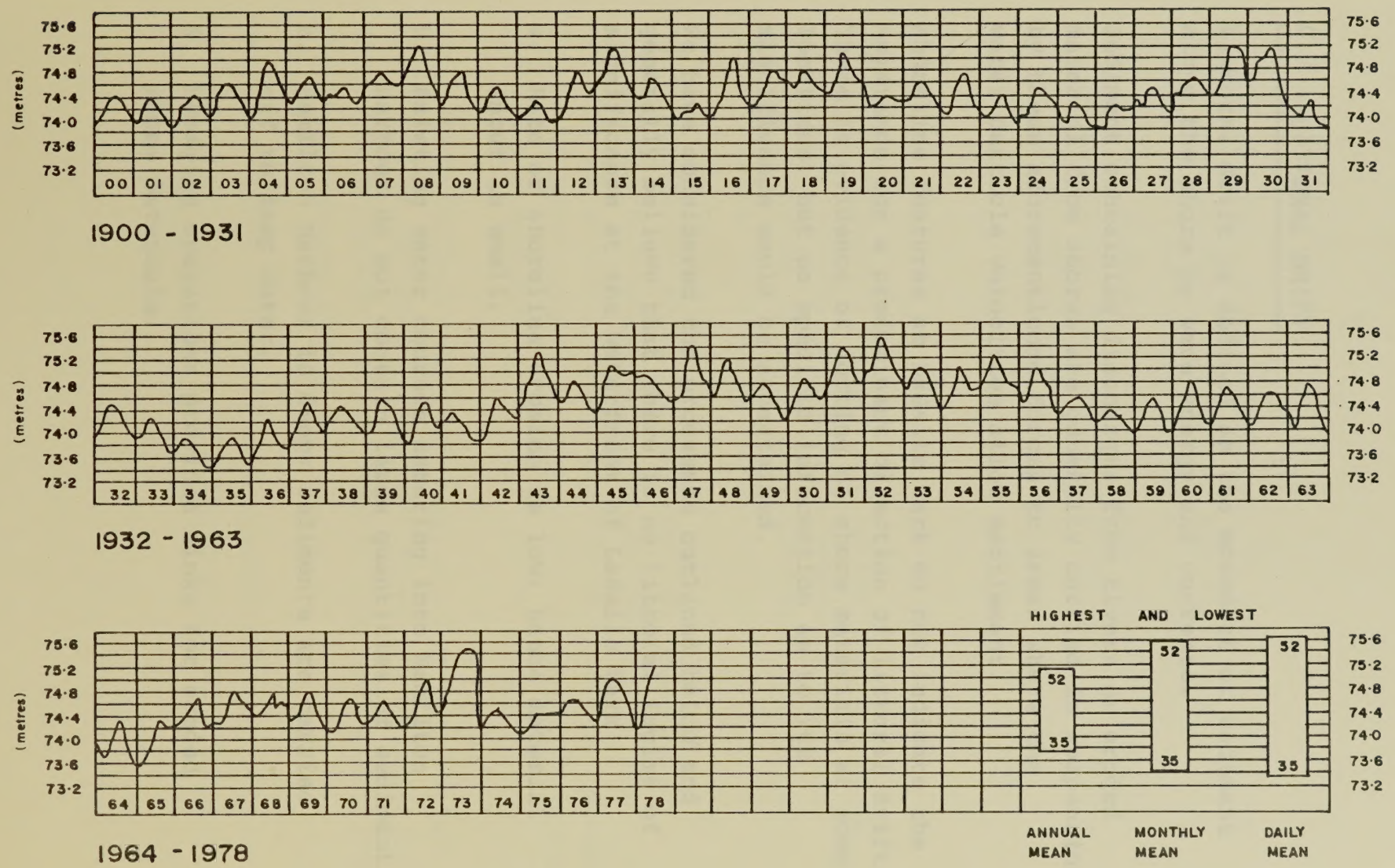


FIGURE 8

HYDROGRAPH OF LAKE ONTARIO WATER LEVELS 1900 TO 1978
(see REFERENCE 4)

4.7 LITTORAL DRIFT

Littoral drift is defined as the movement of sediment along the shore by wave energy and currents.

Sediment containing discharges from rivers or eroded material from shores are generally carried in suspension by these aforementioned forces to areas where the water particle velocities allow settlement.

Shoreline features at LaSalle Park do not indicate the existence nor a predominant direction of littoral drift. There is evidence of sorting of shore materials at some locations, but no specific information as to its significance could be ascertained.

We have considered the processes outlined below and generally believe that there is no littoral regime of significance at the waterfront of LaSalle Park.

a. Rate of shoreline erosion is low; hence material input is small.

b. Existing water courses entering into Hamilton Harbour do not contain large quantities of sediment.

c. Hamilton Harbour is deep: sediments are carried off to deep water.

d. Dredging operations provided sinks for eroded shore materials.

4.8 CURRENTS

In the absence of meaningful data on current patterns within the harbour, it seems likely that, with the exception of wind driven currents, currents of significant strength will only occur in the vicinity of the Burlington Canal where the exchange flow has a local effect (see Reference 5).

4.9 ICE

Ice cover generally appears and establishes itself in the harbour towards the end of December or early January. The ice cover protects the shoreline from erosive forces during the winter.

Ice break-up may start late February or early March but is generally complete by the end of March. The break-up is generally experienced as a slowly increasing circle of open water, starting at the Burlington Channel progressing westward.

Winds from the west and south-west are dominant during the break-up period and sometimes cause ice concentrations along the shoreline between LaSalle Park and Canada Centre for Inland Waters (C.C.I.W.).

These ice flows do have little erosive effects on the LaSalle Park shoreline. Impacts on shore structures are most likely of more concern.

5.0 ENVIRONMENTAL REVIEW

5.1 GENERAL

The purpose of this review section is to outline the major environmental concerns which should be considered in the design and construction of improvements to LaSalle Park shoreline.

5.2 EXISTING CONDITIONS

In general, the shoreline of the park to the east of the dock is characterized by steep slopes, sandy soils, large mature trees (Pine, Oak, Poplar, Birch, etc.), extensive understory shrubbery (Sumac, Dogwood, Witch Hazel, Speckled Alder) and ground cover (Cat-tails, Jewel-Weed, Skunk Cabbage, Trilliums, etc.).

The high bank immediately east of the dock is steep and is suffering erosion in the non-vegetated areas.

The central portion of the shoreline is very low-lying and is therefore wet and marshy. Black Willow, Cat-tails, Trillium, Jewel-Weed, Skunk Cabbage, May Apples, Speckled Alder, etc. are found here.

While this low land area does not appear to contain any unique or rare species, the valley is highly scenic and adds to the diversity of the flora and fauna of the area. The water level of the wetland area is maintained both by the high water table and seepage from the adjacent sandy hills and minor quantities of run-off water.

Immediately east of the low land area is another high steep, sandy bank, the majority of which is covered in vegetation. Two substantial areas, however, are devoid of vegetation and are eroding. This area contains a substantial colony of Bank Swallows which weakens the surface of the shore and therefore contributes to its erosion. In all other respects, this bank is similar to the one to the west, except that erosion appears to be more extreme with several Poplar and Willow trees having fallen into the water.

A variety of bird species can be expected to inhabit the area besides the Bank Swallow colony previously mentioned. These include such birds as flickers, warblers, red wing blackbirds, etc. These, as well as other upperstory species are quite common but will relocate if nesting areas are disrupted by continued human interference.

5.3 DISCUSSIONS

In general, the shoreline environment is highly scenic and diverse and, as such, is of a sufficient quality to be maintained. While it appears that there are no rare or unique environmental features in the park, the recreational experience of the site would be greatly enhanced by its preservation in the present condition. Should improvements to the shoreline result in an increase of public activity in the area, particular care must be taken in the design to prevent disruption of the area while at the same time providing an opportunity to experience the richness of the area. Proper location and design of walking trails will reduce damage and disruption to the site by the public.

Particularly, the Bank Swallow nesting area is vulnerable to disruption. Human interference can destroy nests and harrass the colony resulting in nest abandonment.

The other area which must be treated with care is the central low land area where interference with existing drainage characteristics should definitely be avoided. While the species in the area are resilient, aesthetically their disruption should be avoided. While there will be an increase in human activity in the area, the marshy nature of the area should discourage trampling.

6.0 RECREATIONAL USE

LaSalle Park is the major year round centre for outdoor recreation in the western portion of the City of Burlington. A number of activities and experiences are available in the park (see Figure 9).

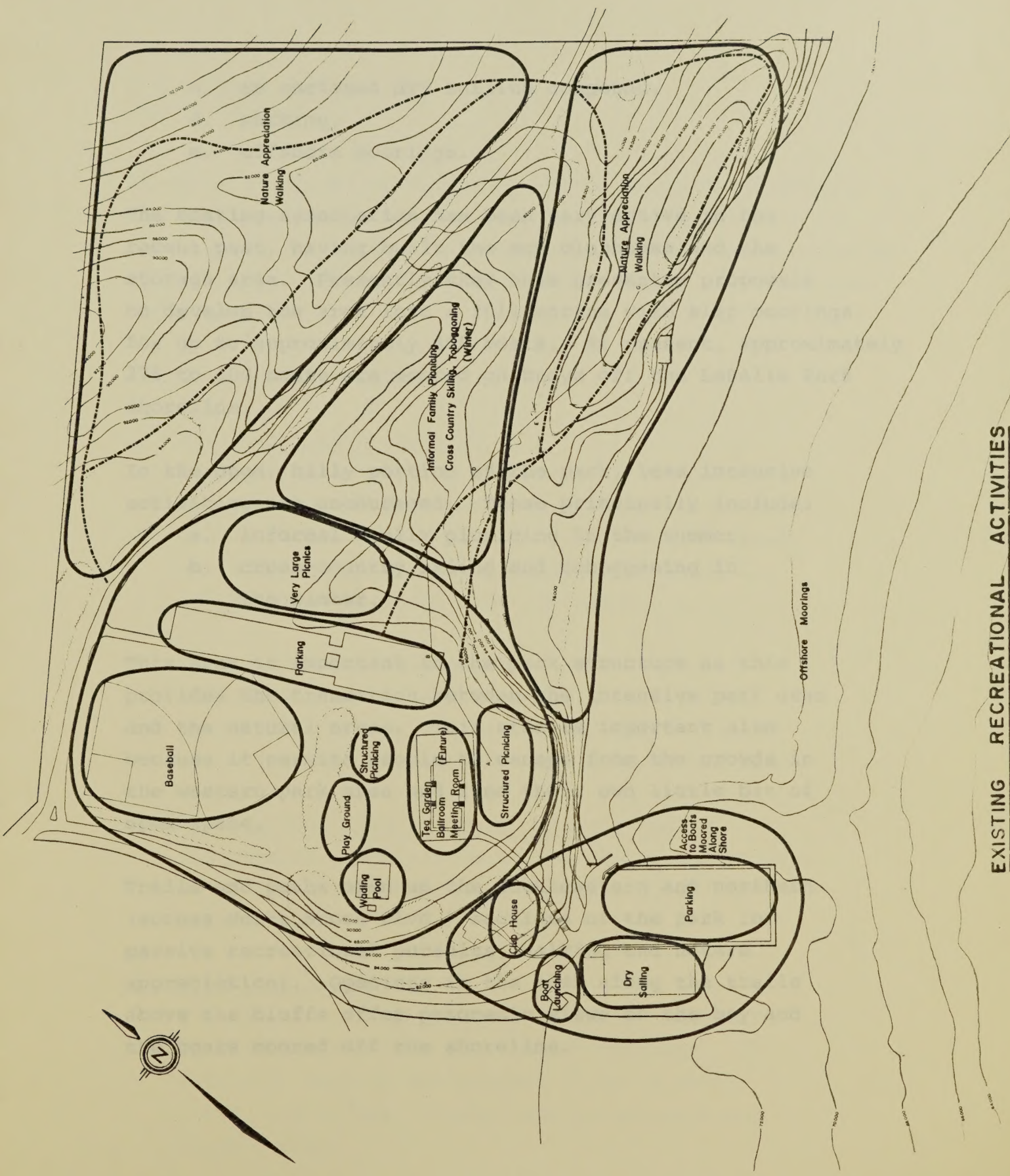
The western portion of the park is given to intensive usages, which include facilities such as:

a. two baseball diamonds,
b. tea garden, ballroom, meeting room and concession in the pavillion,
c. structured picnic areas,
d. children's playground and wading pool,
e. parking.

The baseball diamonds receive heavy usage throughout the summer with several leagues centred here. Permits are available for medium and large family or company picnics. In particular, the flat area immediately east of the parking area is used several times a year for very large gatherings (1000 people). Present plans by local service clubs are underway to restore the pavillion into former splendor. This would then become the hub for activities in the park.

The large dock at the park's shoreline is the centre of boating activities. Facilities associated with this area include:

a. a club house/headquarters for the Burlington Sailing and Boating Association,
b. two boat launches,



EXISTING RECREATIONAL ACTIVITIES

FIGURE 9

c. an enclosed dry sailing compound,
d. parking,
e. offshore moorings.

The boating association has been very active in the recent past, having built the new clubhouse and the storage area. Presently they have presented proposals to develop the area into a full marina with slip moorings for up to approximately 300 boats. At present, approximately 275 to 300 boats are moored on buoys off the LaSalle Park shoreline.

In the open, hilly portion of the park, less intensive activities are encouraged. These principally include:

a. informal family picnicing in the summer,
b. cross-country skiing and tobogganing in the winter.

This area is important in the park structure as this provides the transition between the intensive park uses and the natural areas. This area is important also because it permits people to escape from the crowds in the western park area and find their own little bit of open space.

Trails and paths open up the southeastern and northern (across North Shore Blvd.) sections of the park for passive recreational pursuits (walking and nature appreciation). Openings in the bush along the trails above the bluffs offer panoramic views of the bay and the boats moored off the shoreline.

7.0 DESIGN GOALS

In order to establish specific erosion control strategies, the implications of the previously discussed subjects re protection, environment and recreation are to be coordinated. To this end, certain goals were set. Figure 10 summarizes these goals.

Specific goals identified include:

a. Maintain Natural Setting.
The natural setting of the woodlots in the south section and the north-eastern corners of the park should be maintained intact. Increases in human activity should not be encouraged. This will result in deterioration of the areas.

The central bog area should also be maintained and filling should not be permitted. The low shoreline fronting the bog should not be raised since this will change the character of the area.

b. Develop Pavillion as Major Activity Centre.
The present proposals to revive the pavillion area as the activity centre for the park should be encouraged.

c. Shoreline Erosion.
The erosion of the shoreline must be checked to prevent further loss of valuable property. In addition, erosion has produced 5 to 10 metre (16.5 - 33.0 foot) bluffs next to walkways and picnic areas.

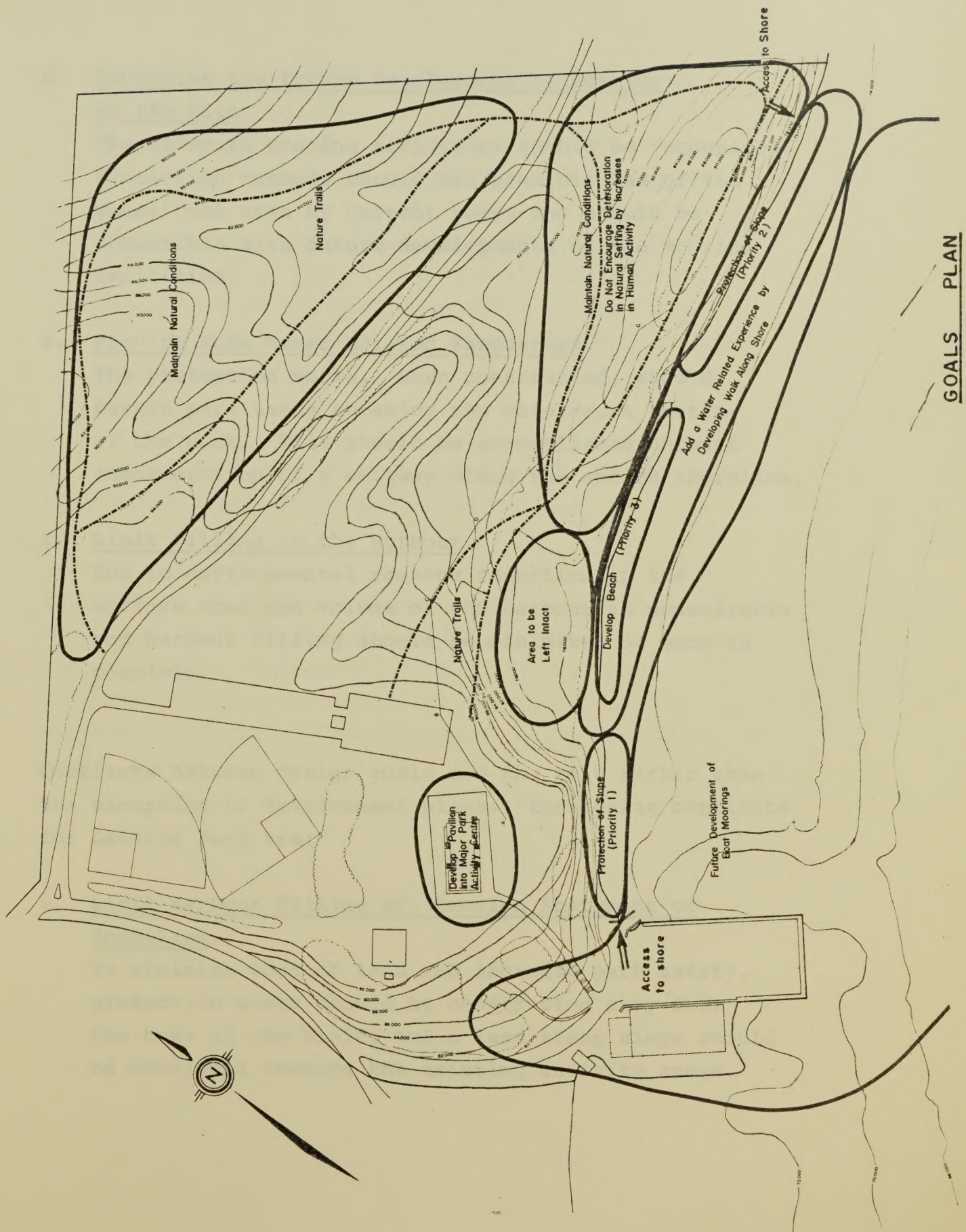

GOALS PLAN
Maintain Natural Conditions
Nature Trails
Maintain Natural Conditions
Do Not Encourage Deterioration
In Natural Setting by Increases
in Human Activity
Access to Shore
Protection of Slope
(Priority 2)
Add a Water Related Experience by
Developing Walk Along Shore
Develop Beach (Priority 3)
Nature Trails
Area to be
Left Intact
Develop Pavilion
into Major Park
Activity Centre
Protection of Slope
(Priority 1)
Future Development of
Boat Moorings
Access
to shore
N

FIGURE 10

d. Recognize the Future Development of Boating at the Site.
The offshore boating activities should be recognized. Protection methods should not prohibit use of the waterfront area by present boats and should be compatible with future developments of the mooring facilities.

e. Provide More Water Related Encounters.
The protection works, when constructed, should permit park users to enjoy the waterfront setting of the park. This should be accomplished through incorporation of a walkway along the entire shoreline.

f. Limit Filling in the Harbour.
Due to environmental reasons reduction in the surface area and volume of the harbour is undesirable and harbour filling should be minimized as much as possible.

Conflicts between design goals are the rule rather than the exception in development plans. Particular conflicts for LaSalle Park are:

a. Limit Harbour Filling vs. Erosion Abatement of Shoreline.
To minimize loss of land and increase park safety, protection works should be constructed away from the base of the bluffs and a less steep slope should be developed towards the existing activity areas.

b. Provision of Water Encounters vs. Maintenance of Natural Setting.
The development of activities along the shoreline may also increase use of woodlot and bog areas.

c. Boating Activities and Erosion Protection.
Future boating activities require additional dredging near the shoreline, thus increasing wave action and necessitating deeper founded protection works.

These conflicts will have to be weighed and compromised in preparing the development alternatives.

For the possibility of stage development, the three sections of shore (high western bluff, low lying centre area, and the high eastern bluff) were identified as to their relative priorities. The bluff areas are considered as requiring most immediate attention, especially the western bluff due to its proximity to the intensive use areas.

8.0 DESIGN CRITERIA

8.1 GENERAL

Specific conditions and constraints of the site and the forces interacting with its shoreline together with environmental and park use considerations are the criteria for the design of a suitable erosion abatement solution.

The previously discussed Goals Plan (see Figure 10) generally incorporates the recreational, environmental and protection priority criteria.

In specific terms the following criteria are to be kept in mind during the development of erosion protection works:

a. Construction access to the shoreline will interfere with present waterfront use but can be tolerated.

b. Construction operations at the mouth of the marshy area are to be minimized.

c. Protection method applied at the mouth of the marshy area is not to alter its drainage.

d. Construction not to take place in May and June (interference with bird nesting).

e. Cutting back of the bluff slopes is to be restricted and reshaped slopes are to be revegetated.

f. Placement of fill in the harbour basin is to be restricted.

g. Incorporate walkway along waterfront.

h. Allow for future boating facilities.

Design criteria of a more technical nature are outlined below:

a. Design wave height,

b. Design elevation,

c. Design slope of stable soil embankments,

d. Vegetation,

e. Stable weight of rip rap or shore unit protection materials,

f. Beach criteria.

8.2 DESIGN WAVE HEIGHT

The foregoing sections have outlined the analysis of available wind and wave data. This analysis determined a significant inner harbour wave height of 1.22 metres (4.0 feet) to be very probable.

At the LaSalle Park shoreline, the design wave height is the height of the wave that will break directly on the

proposed shoreline structure as allowed by the water depth at or before the toe of the structure.

Protection structures at the LaSalle Park waterfront will be located seaward of the present water line. The water depth at this location is fairly uniform and supports a breaker height of 1.5 metres (4.9 feet) (see Figure 11).

The design breaker height is therefore adopted to be 1.5 metres (4.9 feet) and is the actual breaker height of waves initiated to breaking in a water depth of 1.7 metres (5.6 feet) taken at the design high water level.

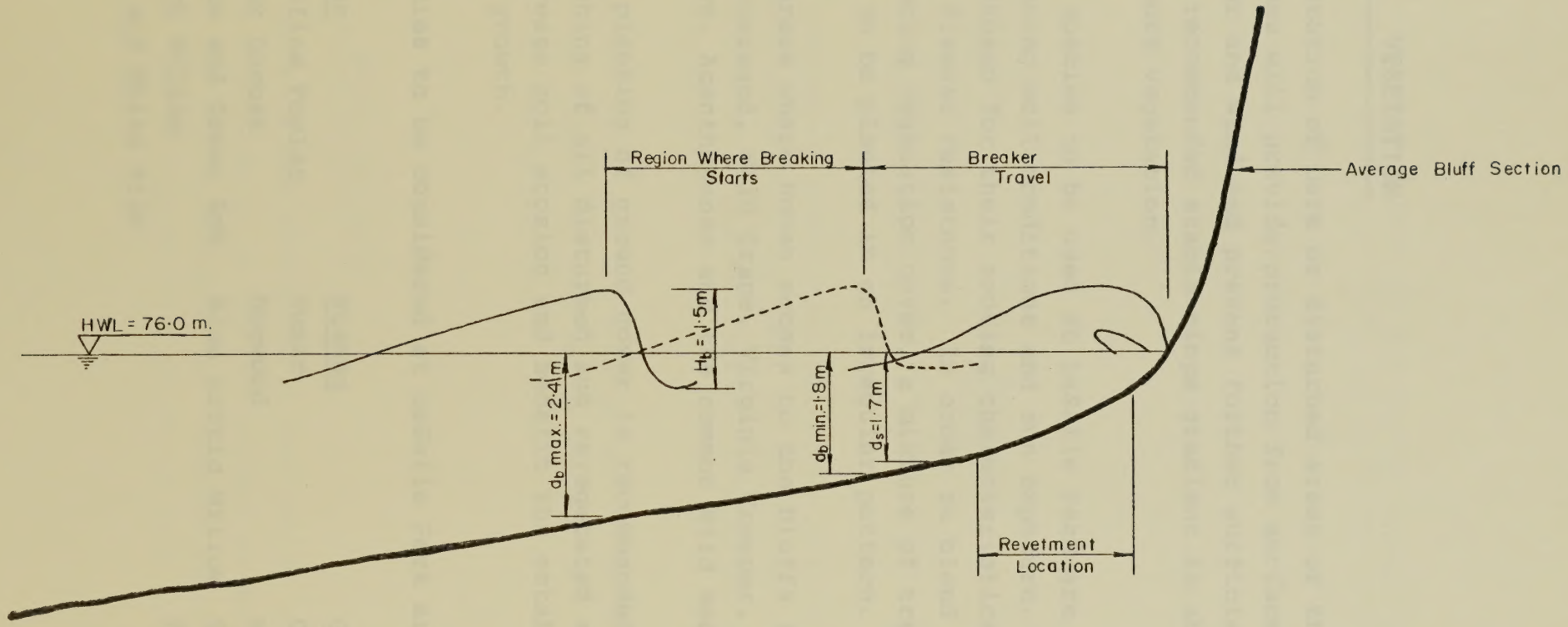
8.3 DESIGN ELEVATION

Any structure at the foreshore of the LaSalle Park waterfront should be founded at a scour free elevation.

We determined this elevation to be 73.1 metres (239.83 feet). Top elevation of protective structures may vary depending on the structure type and wave run-up criteria. The maximum protected elevation is recommended to be 77.1 metres (252.95 feet) IGLD, allowing some overtopping during extreme storms.

8.4 DESIGN SLOPE OF STABLE EMBANKMENT

The soils investigation suggests stable embankments at slopes of 1:1.75 to 1:2.



d_b = DEPTH AT BREAKING

d_s = DEPTH AT STRUCTURE

H_b = BREAKER HEIGHT

SCALE: HORIZONTAL 1:100
VERTICAL 1:500

FIGURE 11

DESIGN WAVE HEIGHT

8.5 VEGETATION

Vegetation of bare or disturbed areas of the bluff slopes will provide protection from surface erosion by water and wind and prevent further surficial slides. The recommended stable slope gradient is able to support vegetation.

The species to be used at LaSalle Park are to match existing soil conditions and sun exposure. They should be chosen for their rooting characteristics, hardiness and disease resistance. In order to blend in with the existing vegetation cover, a mixture of trees and bushes are to be planted in an irregular pattern.

In areas where human access to the bluffs is to be discouraged, Wild Grape, Virginia Creeper, Cotton Easter, Russian Olive, Acanthopanax and the common Wild Red Rose could be planted.

The planting of ground cover is recommended as well. Mulching of all disturbed and revegetated area will decrease soil erosion and benefit the establishment of all growth.

Species to be considered at LaSalle Park are:

Trees	Bushes	Ground Cover
Carolina Poplar	Sumac	Crown Vetch
Black Locust	Dogwood	Willow Herb (Fire Weed)
White and Green Ash	Blue Arctic Willow	Spirea
Black Willow		Perennial Rye Grass
Red and White Pine		

8.6 STABLE WEIGHT OF RIP RAP OR SHORE PROTECTION UNITS

The design of stable rip rap revetments for a particular wave condition is developed around the median size of a stable rip rap particle. Our evaluation of the required median size rip rap for the LaSalle shoreline is tabulated below:

Stable Weight Median Size Rip Rap	Revetment Slope	Approximate Stone Size Cubic Dimension of D 50
0.272 tonnes (600 lbs.)	1:1 1/2 (33°)	450 millimetres (18 inches)
0.182 tonnes (400 lbs.)	1:2 (26°)	400 millimetres (16 inches)

The design of structures utilizing individual large armour units does not need to be refined since unit weights exceed minimum design weights at this design wave condition.

Vertical retaining structures are to be designed for the full impact of the design height of a breaking wave at the structure.

8.7 BEACH CRITERIA

The area of low elevation in the centre of the LaSalle Park shoreline is to be left intact as much as possible. In order not to disturb the drainage pattern of this area, the provision of a beach at this location is preferred.

Since no specific methods for the establishment of undisputable beach development criteria is available, the laboratory test results carried out by C.C.I.W. in 1976 pertaining to this site have been considered.

The testing program concludes that a beach composed of material not smaller in size than 75 - 100 millimetres (3-4 inches) crushed stone will be dynamically stable in the local wave climate at the proposed location. In order to make sure that this material remains within the beach area, the construction of hardpoints will be required.

9.0 EVALUATION OF ALTERNATIVES

9.1 GENERAL

Various methods of erosion abatement have been considered to satisfy the design goals. These methods can be divided to suit the two major components of the shoreline:

a. water's edge treatment
b. bluff slope treatment

The two distinctly different shore profile conditions (high bluff and low marsh), and the specific recreational use and environmental considerations for these areas led to a different approach in shoreline treatment for each.

The water's edge treatment can be divided as follows:

a. bluff toe protection
b. marsh area protection

9.2 BLUFF TOE PROTECTION

Protection strategies are generally designed to dissipate wave energy before or upon reaching the shoreline.

Such strategies are based on the provision of onshore structures such as seawalls, revetments, beaches and beach building structures or offshore structures such as breakwaters.

These alternative protection methods have been considered for the LaSalle Park shoreline and are discussed below.

9.2.1 *BEACHES AND BEACH BUILDING STRUCTURES*

The absence of littoral drift along the LaSalle Park shoreline rules out the application of shore structures (i.e. groynes) aimed at creating beaches.

This condition is unfortunate since a beach has a great capacity to absorb energy due to its long slope which forces waves to break, to run-up and loose energy in friction and height.

The possibility of providing an artificial beach has also been considered. Such an artificial beach would be constructed through the placement of a sufficiently wide strip of granular beach fill at the waterline. This method has been tested in a wave flume of the hydraulics laboratory of the C.C.I.W. (see Reference 6). During this testing program it was found that 75 - 100 millimetre (3-4 inch) granular beach fill assumes a dynamically stable slope at a 1:5 to 1:10 gradient.

The application of such an artificial beach fill program along the entire shorefront would also require the construction of beach anchors. These anchors prevent the lateral moving of stone particles along the shoreline as a result of wave action approaching the beach from directions other than perpendicular to the shore.

We recommend, however, not to pursue the development of artificial beaches along the entire LaSalle Park waterfront for the following reasons:

a. the design of such artificial beach scheme is not without risk, and no fool-proof solution can be offered,

b. another model study would be required to test the complete artificial beach scheme for a variety of wave approaches,

c. maintenance will be required since the beach fill material will reduce in size from attrition and eventually move into deeper water,

d. incompatibility of a beach with boating use of the area (see Design Goals, page 32),

e. undesirable increase of waterfront park use (see Design Goals, page 30).

At the centrally located low area, site conditions and design requirements do warrant the application of a beach type protection scheme. This application will be dealt with in Section 9.3 on Marsh Area Protection.

9.2.2 *SEAWALLS*

Seawall structures can be constructed from timber, concrete, and steel. They can be flexible or rigid.

The vertical face of seawalls generally functions as an efficient energy reflector. Side effects of this reflection are compounded wave agitation and increased scour action at the structure toe. These side effects are the reason for the decreasing number of seawall applications in areas of substantial wave action or boating activity.

The LaSalle dock area is retained by a steel sheetpiled structure which causes wave reflection towards the westerly bluff. Construction of a non-energy absorbing seawall at the toe of the bluff at that location will not dissipate, but increase the general wave agitation of the area.

In view of these disadvantages, we recommend against the use of seawalls at this site.

9.2.3 *REVETMENTS*

The revetment type protective structure is, in our opinion, the most suitable structure for this location, wave exposure and intended use of the waterfront at the bluff locations.

A revetment structure is a compromise between a beach and a seawall. It is a steep beach ensuring its stability with heavy stone, or a sloping seawall partly absorbing and partly reflecting wave energy. A revetment furthermore allows interaction of the park user with the actual waterline if gentle slopes and/or splash berms are incorporated into the design.

The relatively modest wave climate at the site provides the opportunity to consider the application of a variety of newly developed protection methods as an alternative to traditional rip rap revetments.

Eight different types of revetment are shown in Figures 12 a & b. The estimated construction cost per metre based upon 1979 prices together with our comments are listed below:

Revetment Type	Cost/ Metre	Total Revetment Cost	Comments	
			Advantages	Disadvantages
Rip Rap	$395.	$160,000.	-allows settlement -easy maintenance	-difficult access to waterline -rough appearance
Armourstone	$660.	$270,000.	-excellent wave energy absorption -natural appearance -extremely durable	-over-designed
RipRap/ Armourstone combination	$510.	$200,000.	-excellent wave energy absorption -natural appearance -durable	
Terrablocks	$720.	$300,000.	-flexible structure allows establishment of vegetation	-unnatural appearance -differential settlement
Gabion Mattress	$560.	$230,000.	-flexible structure	-collects debris and algae on wires
Fabriform	$560.	$230,000.		-unnatural appearance
Fabricast blocks	$660.	$270,000.		-unsightly appearance
Concrete Step Revetment	$1150.	$460,000.	-unnatural appearance	-high cost.

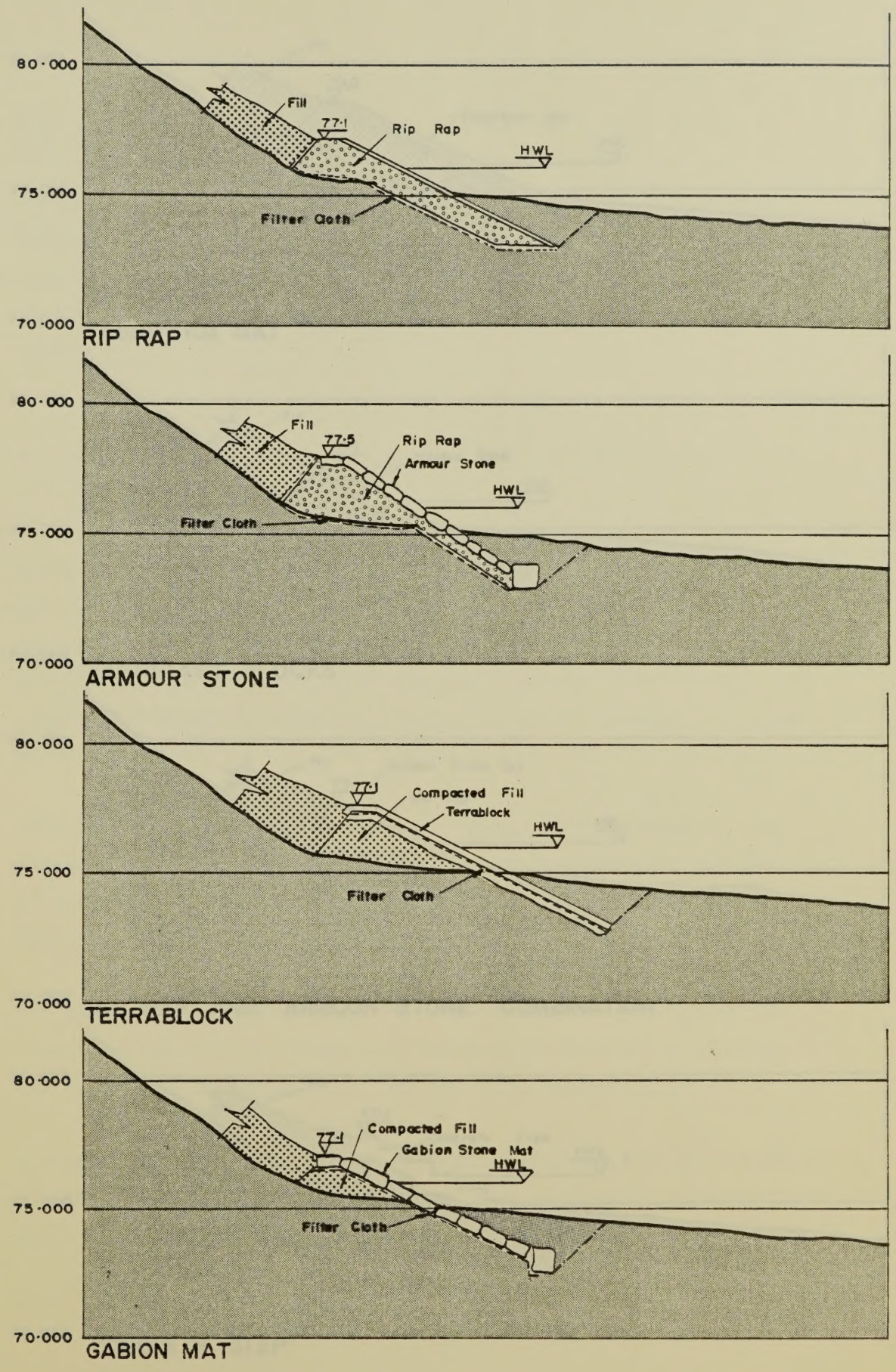


FIGURE 12 a

TYPES OF REVETMENTS

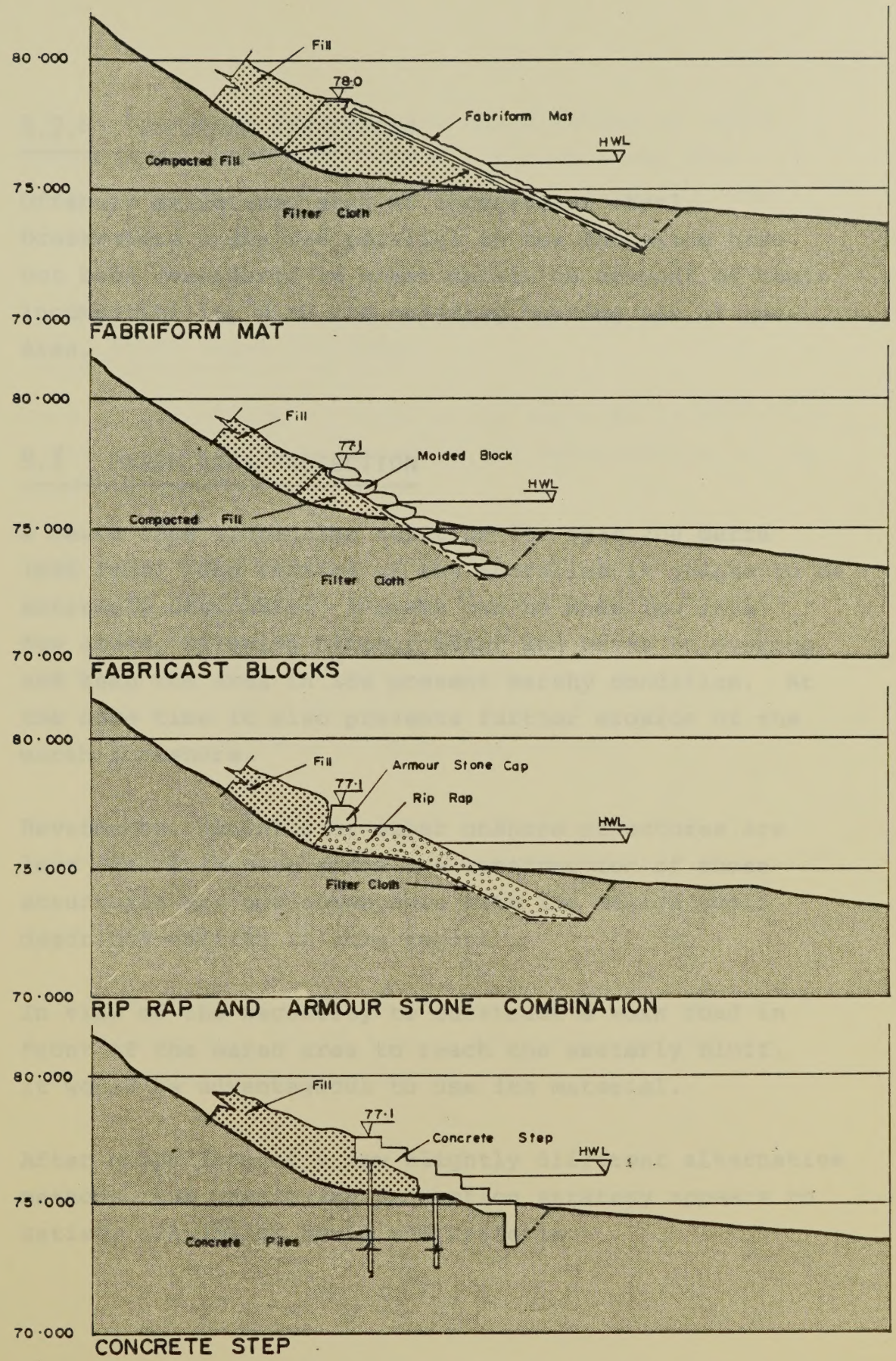


FIGURE 12 b

TYPES OF REVETMENTS

9.2.4 *OFFSHORE STRUCTURES*

Offshore structures such as concrete or steel breakwaters installed parallel to the shoreline have not been considered in great detail on account of their incompatibility with the existing boating use of the area.

9.3 MARSH AREA PROTECTION

A beach type protection solution for this 200 metre (656 foot) long section of the shoreline is judged to be extremely desirable. A beach can be made low in a few areas, allowing harbour water and waves to overtop and keep the area in its present marshy condition. At the same time it also prevents further erosion of the marsh foreshore.

Revetments, seawalls or other onshore structures are less desirable here since the construction of those structures are not compatible with the design goals described earlier in this report.

In view of the necessity to construct a work road in front of the marsh area to reach the easterly bluff, it would be advantageous to use its material.

After comparison of a few slightly different alternative methods, one particular protection strategy appears to satisfy all design goals and criteria.

This solution is based on the construction of small armourstone hardpoints located in such a way that they protect and anchor the work road material (see Figure 13).

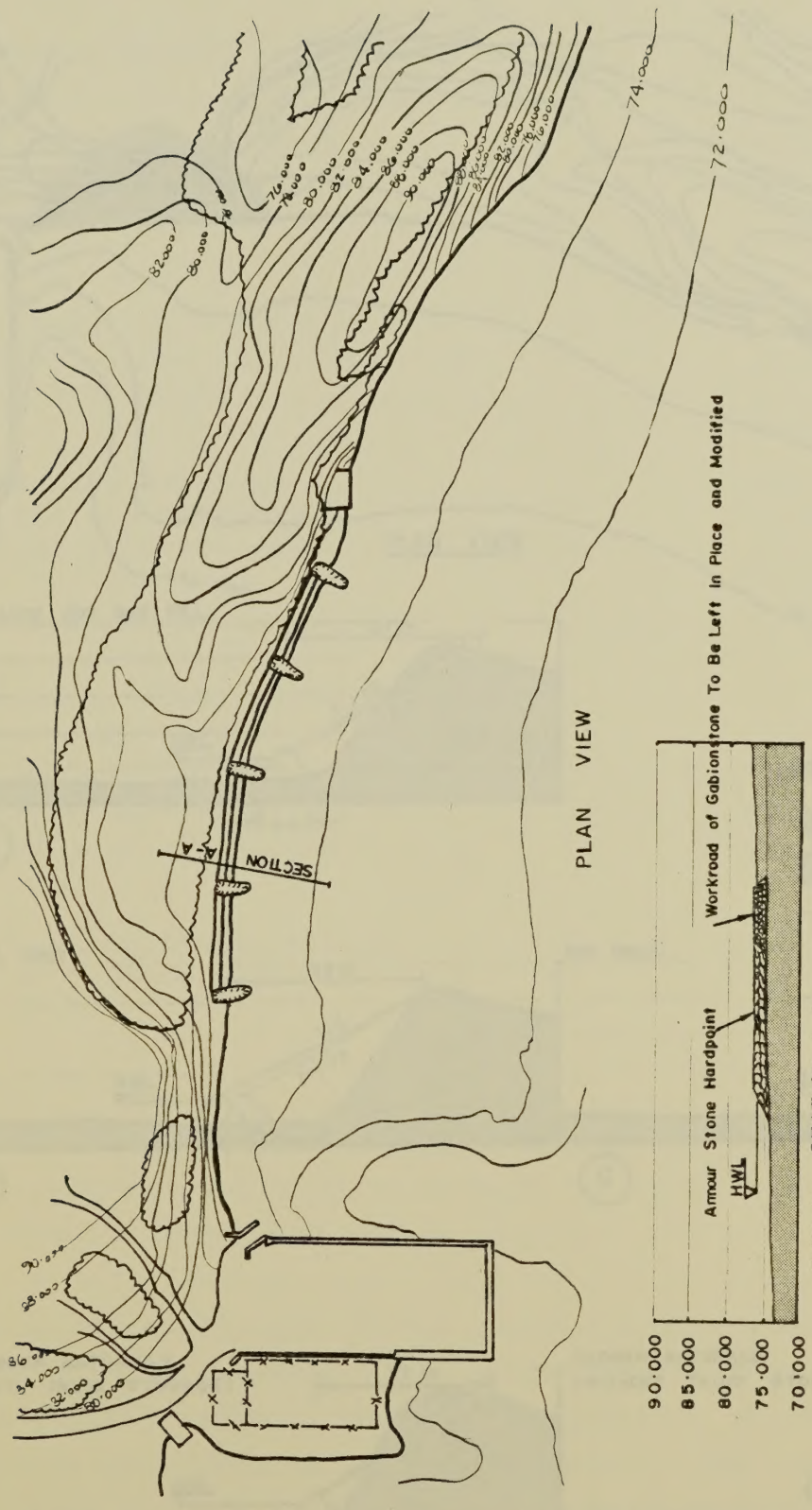
9.4 BLUFF SLOPE TREATMENT

Erosion protection of bluff slope surfaces is generally accomplished through reshaping and revegetation of the bluff slope.

Reshaping may consist of the placement of fill at the bluff toe, excavation of the bluff rim or a balanced cut and fill combination. The nature of bluff instability and the usage of areas near bluffs sometimes requires the construction of substantial retaining structures or terracing schemes.

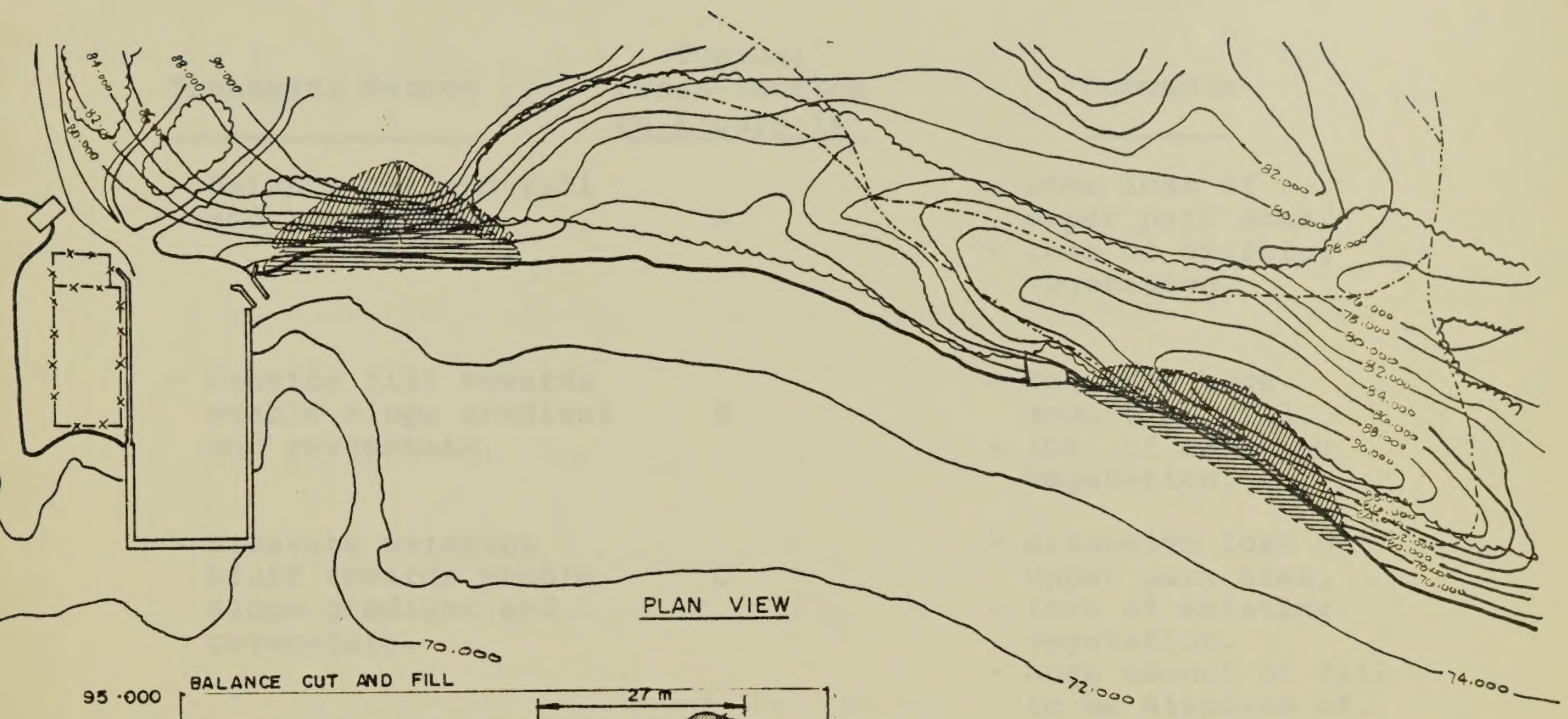
The bluffs at LaSalle Park do not require such substantial stability and erosion protection provisions on the slope itself once the bluff toe is protected from wave action.

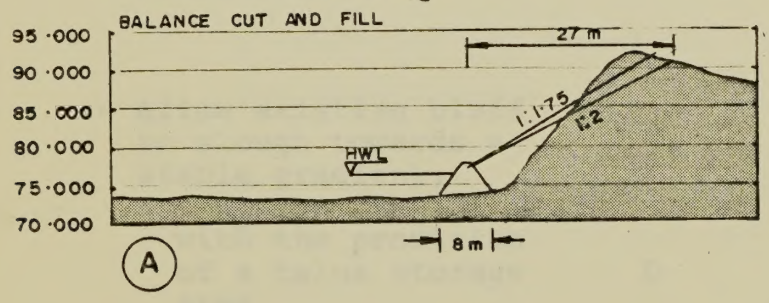
Alternative slope surface protection provisions for the LaSalle Park bluff slopes are described below and presented in Figure 14.

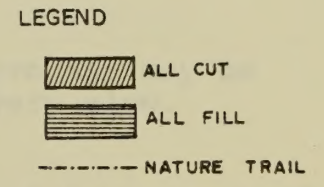


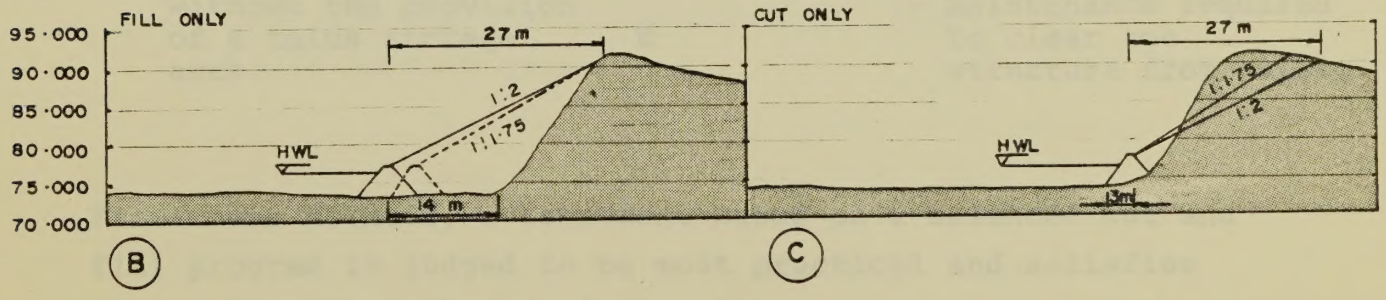
MARSH AREA PROTECTION

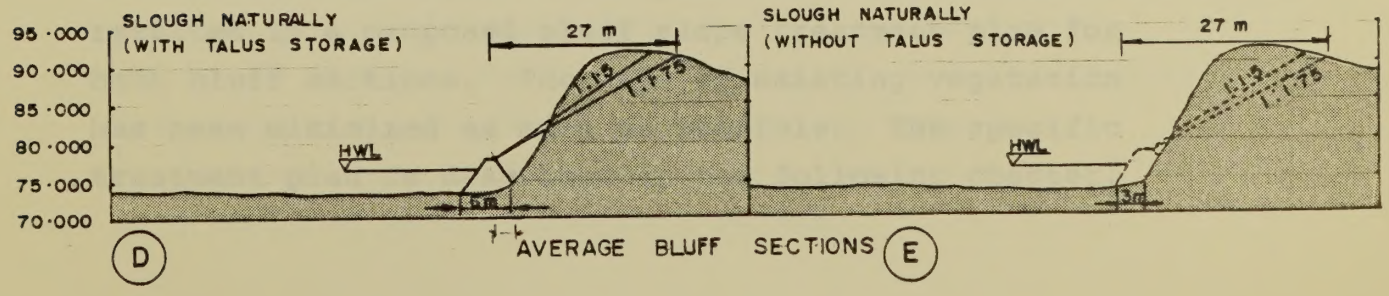
FIGURE 13











AVERAGE BLUFF SECTIONS

BLUFF SLOPE TREATMENT

FIGURE 14

Treatment Method	Typical Cross-Section on Figure 14	Comments
- Balance cut and fill and revegetate.	A	- some loss of upper park area, - loss of existing vegetation.
- Provide fill towards stable slope gradient and revegetate.	B	- requires huge amount of fill, - loss of existing vegetation.
- Excavate existing bluff towards stable slope gradient and revegetate.	C	- extensive loss of upper park area, - loss of existing vegetation, - huge amount of fill to be disposed of.
- Allow existing bluff to slough towards a stable gradient,		
with the provision of a talus storage area,	D	- process may be very slow.
without the provision of a talus storage area.	E	- maintenance required to clear toe structure from talus.

From these methods, a treatment based on a balanced cut and fill program is judged to be most practical and satisfies the earlier described design goals.

A detailed evaluation of the pertinent site conditions resulted in a proposed bluff slope treatment plan for both bluff sections. The loss of existing vegetation has been minimized as much as possible. The specific treatment plan is described in the following chapter.

10.0 PROPOSED PLAN

10.1 GENERAL

The recommended erosion protection program for the LaSalle Park shoreline is shown on Figure 15 (Appended).

This program contains four types of construction:

a. A revetment structure at the toe of the westerly and easterly bluffs.

b. A hardpoint and beach fill scheme at the low centre area.

c. The placement of imported and on-site excavated soils at the toe of the westerly and easterly bluffs.

d. The revegetation of excavated and filled in bluff surface areas.

10.2 REVETMENT

The revetment consists of 600 to 900 millimetres (24 to 36 inches) selected armourstone slabs placed on a body of rip rap material above the low waterline. The surface layer of the underwater slope consists of 450 - 600 millimetres (18 to 24 inches) rip rap material. The structure is provided with a splash berm to accommodate wave overtopping during heavy storms. This berm area can be utilized as a walkway.

The completed structure will protect the backshore from further erosion, does reflect less wave action than a vertical wall and can be constructed or later modified to allow the installation of boating facilities. The encroachment of the protection works into the harbour is approximately 10 to 15 metres (33 to 50 feet).

10.3 HARDPOINTS AND BEACH FILL

The hardpoints will consist of single, cubic shaped armourstones grouped together to form a permanent beach head.

These beach heads located approximately 40 metres (131 feet) apart along the shore will function as anchors for the granular beach fill.

The beach fill is placed between and slightly behind the hardpoints and consists of 75 to 125 millimetre (3 to 5 inch) stone.

The combination of beach heads and beach fill is expected to stabilize the foreshore of the marsh area. It should be realized that this method is not totally without risk, since the beach fill material will be directly exposed to wave and ice action. It should also be noted that the installation of the hardpoints without the beach fill will most likely also stabilize the shoreline.

In spite of these uncertainties we feel that this solution is the best method available to stabilize the shoreline and leave the marshy backshore intact.

10.4 SLOPE SURFACE TREATMENT

10.4.1 *WEST BLUFF*

The proposed treatment of the west bluff consists of the following operations:

a. Excavation at the top of the bluff.

b. Placement of the excavated material on the lower bluff surface areas.

c. Placement of imported fill material immediately above and behind the protection works.

d. Revegetation of entire reshaped bluff surface area.

The extent of these operations is indicated on the proposal drawing, Figure 15.

The excavation of the top of the bluff will be limited to a bluff rim recession of approximately 5 metres (16 feet). The bluff slope itself will have a 1:1 3/4 gradient.

Clearing of existing vegetation is limited to shrubbery and small trees and needs to be done predominantly in the upper east corner.

10.4.2 *EAST BLUFF*

The east bluff is a very natural and undisturbed area.

In order to minimize total destruction of this park feature, we propose the following bluff treatment:

a. Placement of imported fill material immediately behind the protection work.

b. Leave the near vertical bluff sections as they are.

c. Revegetate bare upper bluff surface areas.

d. Revegetate the fill area in front of the steep bluff section with difficult to trespass bushes and fast growing trees.

The extent of these operations is indicated on the proposal drawing, Figure 15 (Appended).

Clearing of existing vegetation involves only shrubbery and easily replaceable small trees along the waterline. The remaining near vertical bluff face will not pose a safety hazard if park visitors are not led to it. The steep face itself is judged to be fairly stable once the toe protection is in place, and will become increasingly protected from rain and wind, when vegetation in front of it matures.

11.0 COST ESTIMATES

The estimated cost of the total protection program is based on 1979 prices and is specified as follows:

Revetment Structure,		
West Bluff Toe	125 metres* @ $550.	$ 69,000.
East Bluff Toe	265 metres* @ $490.	$130,000.
Hardpoints		$ 9,000.
Granular Beachfill		$ 27,000.
Slope Excavation and Filling Operation		$ 28,000.
Revegetation		$ 30,000.
Contingencies, design engineering, construction supervision and overhead		$ 58,500.
		$351,500.

* *The price per metre has been estimated using specific site conditions and construction methods.*

Material placement prices used are:

Armourstone	*$18. per tonne*
Rip Rap	*$10. per tonne*
Gabion Stone	*$ 8. per tonne*
Filtercloth	*$ 5.50 per* m^2
Earth Fill	*$ 5.00 per* m^3
Earth Moving	*$ 3.00 per* m^3

12.0 SPECIAL CONSIDERATIONS

12.1 PROJECT PHASING

In the event that phasing of the project will be considered, we wish to make the following comments.

The westerly bluff section has been given first priority for protection on account of park safety and property loss (see goals plan, Figure 10).

It is impossible, however, to undertake construction work at the toe of the easterly bluff without suitable access at the waterline. A construction program is therefore to be scheduled as follows:

a. Place required rip rap and beachfill materials along the entire waterline and shape this material into a work road.

b. Start construction of the revetment structure at the east project limits.

c. Carry out backfilling and bluff slope excavation at the same time.

d. Complete protection and slope work progressing westward.

e. Carry out revegetation program upon completion of the shoreline works.

In view of the above suggested construction program, we recommend to implement the proposed protection works uninterrupted preferably starting early July.

12.2 PARK AMENITIES

Special features to enhance park use can be incorporated into the engineering design of the proposed protection program. The amenities identified on the goals plan are:

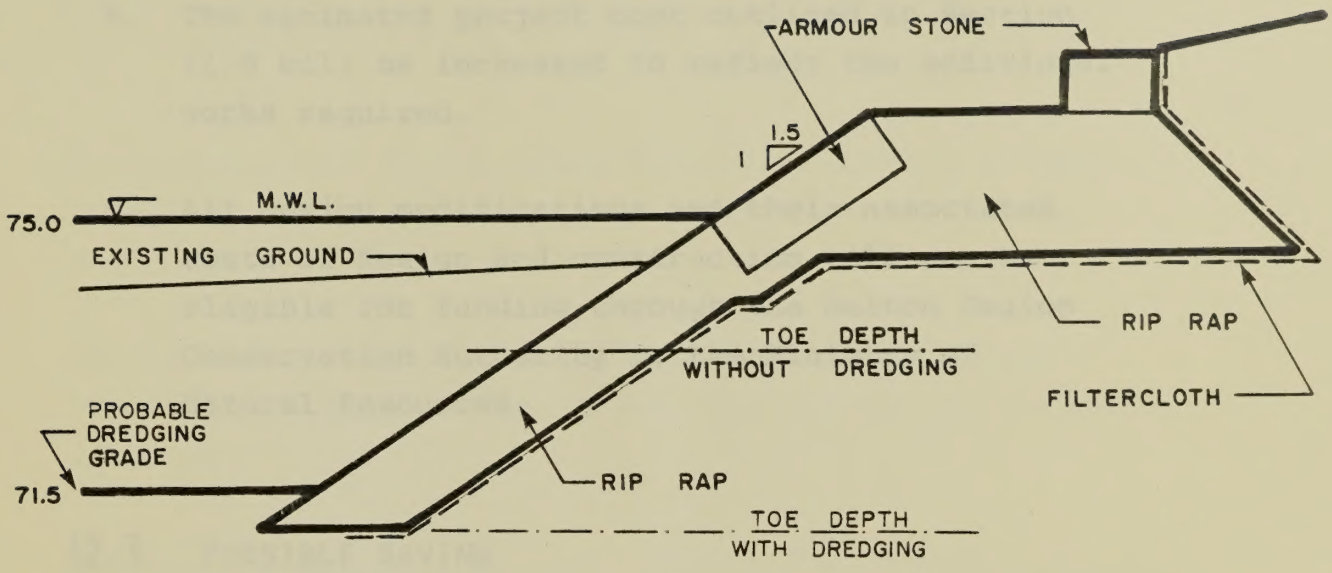
a. stairways to provide access to the shore walk,
b. incorporation of access points to floating dock arrangements.

The provision of stairways is relatively simple, and requires no specific modification of the proposed plan.

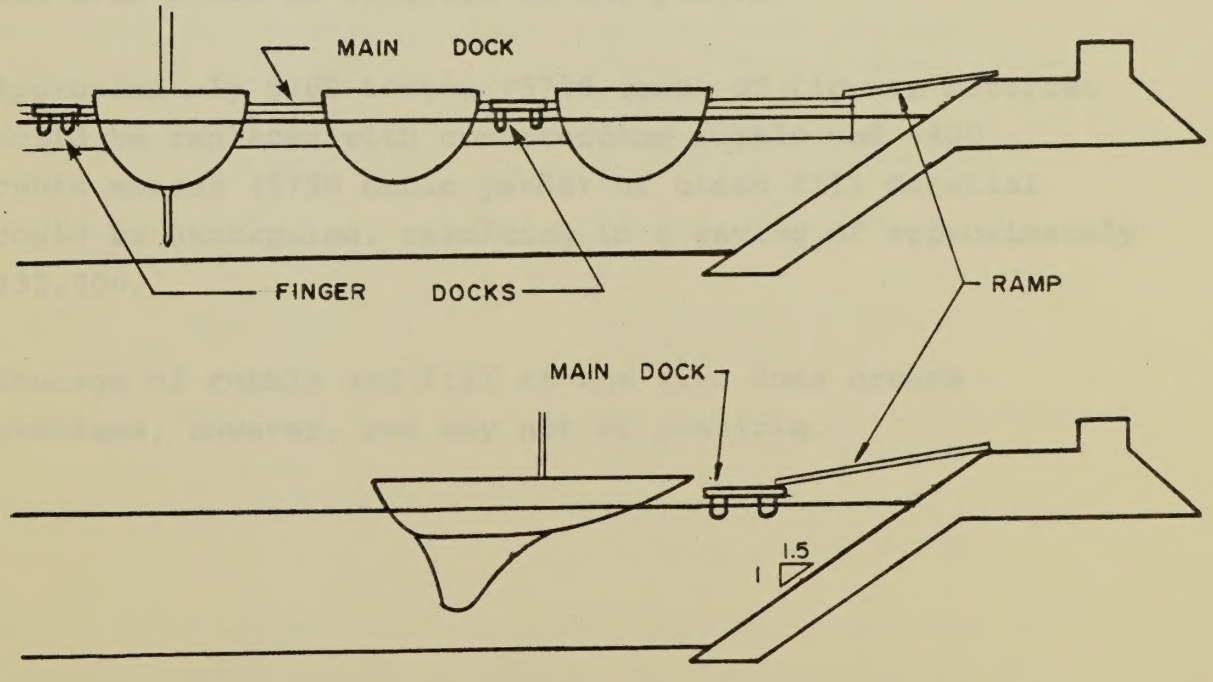
It should be noted that the shoreline erosion abatement works recommended assumes that no major dredging works will take place immediately adjacent to the revetment to accommodate boating facilities. Boating facilities very close to the revetment usually require deep water and necessitate dredging works (Refer to Figure 16).

In the event boating facilities are contemplated adjacent to the revetment which require major dredging works then the following consequences will take place:

a. The protection works shown on Figure 15 will have to be re-evaluated and redesigned to accommodate the boating facility (i.e revetment to be founded deeper, dredging works, additional construction materials, etc.).



AVERAGE REVETMENT SECTION SCALE 1:100



TYPICAL BOAT DOCKING ARRANGEMENTS SCALE 1:200

FIGURE 16

b. The estimated project cost outlined in Section 11.0 will be increased to reflect the additional works required.

c. All design modifications and their associated costs of design and construction will not be eligible for funding through the Halton Region Conservation Authority or the Ministry of Natural Resources.

12.3 POSSIBLE SAVING

Rubble and excavated soils from construction projects in the area could be utilized in the project.

Approximately 5200 tonnes (5720 tons) of rip rap material could be replaced with construction rubble and 4400 cubic metres (5750 cubic yards) of clean fill material could be stockpiled, resulting in a saving of approximately $35,000.

Storage of rubble and fill at the site does create problems, however, and may not be possible.

13.0 REQUIRED DESIGN APPROVALS

Construction of the proposed works can proceed if the required design approvals are obtained and funds are secured.

The design of the proposed works recommended herein should be formally reviewed and approved by the following agencies:

Agency	Reason for Review
-Hamilton Harbour Commission	-re their control of, and responsibilities for activities within Hamilton Harbour.
-Ministry of Natural Resources	-review done through Conservation Authorities.
-Hamilton Region Conservation Authority	-re jurisdiction of water area of Hamilton Harbour.
-Halton Region Conservation Authority	-re jurisdiction of land area.
-Federal Department of Transport	-re Navigable Waters Protection Act.
-City of Hamilton	-re suitability of design, allocation of funds.
-City of Burlington	-re suitability of design, allocation of funds.

It is anticipated that the above approval procedure will require approximately 3 months. We furthermore believe that no major objections to the proposed plan will be raised. We base this opinion on the urgent need to protect valuable parkland and the nondisruptive nature of the recommended protection method.

14.0 FUNDING

The full extent of the recommended protection structures and slope surface treatment is required to combat the erosion of the LaSalle Park shoreline.

On this basis, financial assistance can be sought from the Provincial Government, through the Ministry of Natural Resources. It is our opinion that the project qualifies for assistance under the Conservation Authorities Act.

This assistance will be capital funding of 55% of the total estimated project cost.

We were furthermore informed, by the Halton Region Conservation Authority, that the Halton Region Conservation Authority's current funding policy on benefitting municipal capital projects could provide an additional capital funding of 5% of the total estimated project cost.

The remaining 40% will have to be funded by the two benefitting municipalities, the Cities of Burlington and Hamilton, through a cost sharing agreement.

REFERENCES

Reference 1 - *"Geotechnical Investigation for LaSalle Park Slopes, Burlington, Ontario", prepared by Terraprobe Limited for F.J. Reinders and Associates Limited, Project No. 781, April 1979.*

Reference 2 - *"Canadian Normals, Volume 3", by Environment Canada, Atmospheric Environment, Downsview, Ontario, 1975.*

Reference 3 - *"Shore Erosion Protection - Burlington Bay", Report 75-4 by Mr. T.M. Dick, Chief, Hydraulics Research Division, Canada Centre for Inland Waters, Burlington, Ontario.*

Reference 4 - *Miscellaneous Publications, by Canadian Hydrographic Services, Department of Fisheries and Oceans and Inland Water Directorate, Department of the Environment.*

Reference 5 - *Working Papers, Halton Wentworth Waterfront Study, by Acres Consulting Services Ltd., December 15, 1972.*

Reference 6 - *"Shore Erosion Protection - Burlington Bay", Report 76-4 by Mr. T.M. Dick and Mr. M.G. Skafel, Hydraulic Research Division, Canada Centre for Inland Waters, Burlington, Ontario.*

GLOSSARY

ABATEMENT

A lessening or reduction.

ARMOURSTONE

A large, angular quarried stone, used for the construction of shoreline protection works.

ATTRITION

The act of gradual wearing away or grinding down by friction.

BACKSHORE

The zone of the shore lying above the foreshore and acted upon by waves only during severe storms, especially when combined with high water level.

BEACH ANCHOR

A shore protection structure built at shorelines to retain beach materials.

BERM

Shoulder, splash area, earth mound.

BLUFF

A high steep bank or a cliff.

BLUFF RIM

The outer edge of a bluff (see bluff).

BREAKWATER

An offshore structure protecting a shore area from wave attack.

C.C.I.W.

Canada Centre for Inland Waters.

FETCH

An area in which waves are generated by wind having constant direction and speed.

FINGER DOCKS

A small dock anchored to a main dock providing access to individual boats.

FORESHORE

The part of a shore traversed by the uprush and backrush of waves.

GEOLOGY

The structure of the earth crust in a given region.

GROYNES

A shore protection structure built (usually perpendicular to the shoreline) to trap littoral drift or retard erosion of the shore.

HARDPOINT

A non-erodible protrusion into the water.

I.G.L.D.

International Great Lakes Datum mean water level at Father Point, Quebec.

I.J.C.

International Joint Commission.

MULCHING

Organic ground cover spread to prevent evaporation of water from soil, freezing of roots, etc.

PIEZOMETER

An instrument for measuring water pressure in soil.

REVETMENT

A facing of stone, concrete, etc. built to protect a scarp or an embankment against erosion by wave action.

RIP RAP

A small sized quarried stone randomly placed in a layer to prevent erosion of a shore.

SEAWALLS

A structure separating land and water areas, primarily designed to prevent erosion and other damage due to wave action.

SLOUGHING

A natural process of slipping and sliding of the surface layers of soil in a bluff due to instability caused by run-off, groundwater seepage, etc.

TALUS

A pile of rock or soil debris at the foot of a cliff.

UPPERSTORY SPECIES OF BIRD

Birds preferring to nest above ground level.

WAVEFRONT

A line formed by a propagating wave at right angle to the direction of movement.

WIND ROSES

A diagram showing the frequency and intensity of wind from different directions for a particular location.

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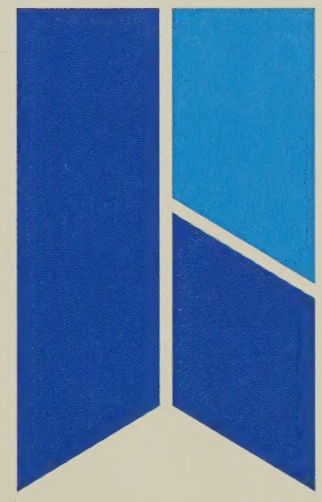

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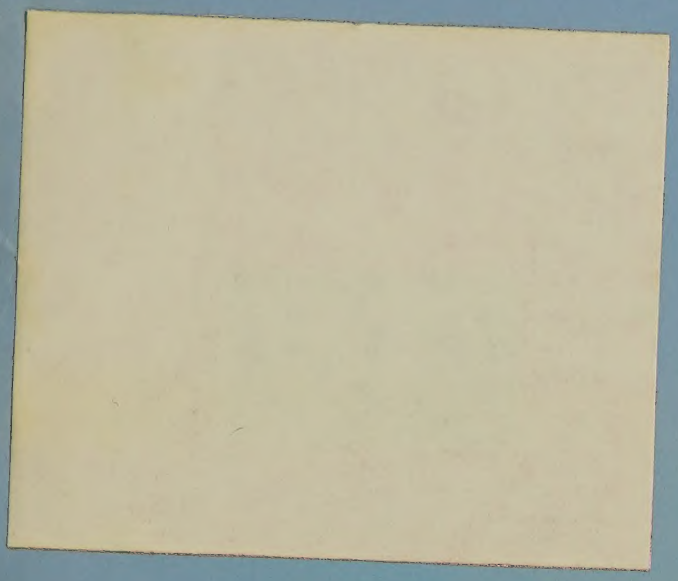

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